CORNEAL TOPOGRAPHIC CHARACTERISTICS OF PERSONS SEEKING LASER REFRACTIVE SURGERY

DISSERTATION SUBMITTED FOR

MS (Branch III) Ophthalmology

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY
CHENNAI

APRIL - 2014

CERTIFICATE

Certified that this dissertation entitled **"CORNEAL TOPOGRAPHIC CHARACTERISTICS OF PERSONS SEEKING LASER REFRACTIVE SURGERY"** submitted for MS (Branch III) Ophthalmology, April 2014, is the bonafide work done by **DR.MAYURA PRIYA.V.**, under my supervision and guidance in the Cornea Clinic of Aravind Eye Hospital and Post Graduate Institute of Ophthalmology, Madurai, during her residency period from May 2011 to April 2014.

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DECLARATION

I **DR.MAYURA PRIYA.V** solemnly declare that the dissertation titled **"CORNEAL TOPOGRAPHIC CHARACTERISTICS OF PERSONS SEEKING LASER REFRACTIVE SURGERY"** has been prepared by me. I also declare that this bonafide work or a part of this work was not submitted by me or any other for any award, degree, diploma to any other university board either in India or abroad.

This dissertation is submitted to the **Tamil Nadu Dr.M.G.R Medical University**, Chennai in partial fulfillment of the rules and regulation for the award of **M.S. Ophthalmology (Branch III)** to be held in April 2014.

Place : Madurai

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ACKNOWLEDGEMENT

I acknowledge with gratitude the many people who have contributed to the completion of this dissertsation.

I thank my guide, **Dr.M.Srinivasan**, Professor, Department of Cornea and Director, Aravind eye hospital, Madurai, whose dynamism and excellent motivation has led me to the undertaking of this study to successful completion.

I am forever grateful to my mentor **Dr.N. Venkatesh Prajna**, Chief of Cornea services and Director – Academics, for his constant encouragement and support throughout my residency.

I am indebted to **Dr.Sean Socrates D Silva, Dr.Jeena Mascarenhas** and **Dr.Rahul Vasudevan,** Consultants, Cornea services, who reviewed my work and provided critical evaluation and guidance for this study**.**

I thank **Dr.R.D.Ravindran**, Chairman of Aravind eye hospital, Madurai for his dedication in providing a good work culture.

I express my heartfelt thanks to **Dr.P.Namperumalsamy,** Chairman Emeritus & Director of Research and **Dr.G.Natchiar**, Director Emeritus, Human Resources Department, whose untiring dedication to the prevention of needless blindness in this community has inspired and will continue to inspire innumerable young ophthalmologists like me.

I take this opportunity to pay my respects and homage to **Dr.G.Venkataswamy,** our founder, whose ideals and philosophy have guided this institution in all its successful endeavours.

This dissertation could not have been completed without the invaluable help of **Mr.Vijayakumar,** biostatistician and the paramedical staff of Cornea services - the clinic sisters and technicians.

I would fail in my duty if I didn’t thank the countless patients who have been the learning ground for my study and my residency.

Last but not least, I thank my parents and brother for all their sacrifices and unfailing love towards me.

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Part I

INTRODUCTION

From the historical sandbags used on eyes for flattening the corneas to radial keratotomies, Laser refractive surgeries have come a long way to stop people from waking up each day to a blurred world. It has marked a significant improvement in the science of vision correction by promising a high degree of precision and safety. It has also become one of the most sought after elective procedures for providing a spectacle or contact lens free vision both for cosmetic and professional reasons.

Each individual cornea is different and unique even between two eyes of the same individual. The more information we get about the surface of the cornea, much easier is it to understand its properties and to devise ways to sculpt the cornea to the individual's requirement of eagle eye vision. Laser refractive surgery being an elective procedure, it is only all the more important that the utmost quantity and quality of results are to be anticipated by the surgeon beforehand.

The important aspect of preoperative examination lies in proper screening of cases at risk for keratectasia as it is the most severe and dreaded complication of any refractive surgery. The objective is not only to detect the cases with mild ectasia but also to characterize each cornea in terms of their risk or susceptibility to undergo biomechanical failure or ectasia[1]. This has been revolutionised by the advent of corneal topography. The clinical diagnosis of corneal ectasias has been conventionally made by either a loss of best corrected visual acuity or by slit lamp bio-microscopy findings. But corneal topography can pick up the subtle and subclinical changes in the corneal surface secondary to ectatic disorders before the clinical manifestations occur[1]. This provides an edge for detection of cases which are clinically normal but are in fact ectatic or at risk for ectasia.

There are no population based studies for the topographic analyses of such corneas. The purpose of this study was to extrapolate and analyze the corneal characteristics of these clinically normal persons rejected for laser refractive surgery at a tertiary eye care institute.

CORNEAL ANATOMY AND OPTICS

Cornea is the most powerful refractive element of the eye[2] which contributes to about 43 D (70%) of refractive power to the eye out of the total 60 D. As the refractive power is determined by the shape of the corneal surface, even a minor modification on its surface can lead to significant alteration of the images formed on the retina.

CORNEAL DIMENSIONS:

The anterior surface of cornea is elliptical with an average horizontal diameter of 11.5 mm and vertical diameter of 10.6mm.

The posterior surface of cornea is circular with an average diameter of 11.5mm.

The corneal thickness varies from 0.52mm at the centre to 0.67mm peripherally and about 1.2mm at the limbus.

The normal human cornea is both aspherical and variable in curvature. It has got different radii of curvature at different points along the same meridian with central steepening and peripheral flattening giving a prolate surface. Asphericity varies even among different meridia of the same cornea. The anterior and posterior radii of curvature of the central optic zone of cornea are approximately 7.8mm and 6.5mm respectively.

The average corneal power is 48.6 D anteriorly and -6.8 D posteriorly. Therefore the net refractive power of cornea comes to about 43 D. By 30 years of age it flattens about 0.5 D and by age 70 years it steepens about 1 D.

OPTICAL ZONES OF CORNEA:

For practical and functional purposes, the surface of the cornea can be divided into four regions[10]:

1. Central zone
2. Paracentral zone
3. Peripheral zone
4. Limbal zone

1. **Central zone:**

   It is approximately 4 mm in diameter and is responsible for formation of image at fovea. It is also called the apical zone or corneal cap. It is more spherical, symmetrical and optically important. Here the radius of curvature does not vary by more than 1 D or 0.05mm and hence the difference in refraction will be less than 0.25 D.

2. **Paracentral zone**:

   It has an approximate diameter of 4-8mm. It is mostly spherical but compared to central zone it is slightly flatter. Along with the central zone it forms the optical zone of the cornea. The curvature of this zone markedly changes after radial keratotomy. Its topography becomes important in conditions of dim illumination when the pupil is dilated.

3. **Peripheral zone:**

   The diameter is about 8-11 mm. Here the cornea flattens more, thereby increasing the asphericity.

4. **Limbal zone:**

   It forms the corneal rim. It has a width of about 0.5mm at an average which abuts the sclera. Changes in dimension of this zone because of surgery can influence the shape of the central regions of cornea.

PLANES AND MERIDIA OF CORNEA:

The introduction of multiple planes of intersection through the cornea can convert the cornea from a three dimensional structure to a two dimensional one. They are as follows:

1. **Meridional plane:**

   A plane through the centre of the cornea is called a meridional plane or tangential plane. They are specified in polar coordinates with the origin at the centre, the angular position of 0 degrees at the 3'o clock position and the angles increasing in a counter clockwise manner.

2. **Corneal meridia:**

   These are the intersection of meridional planes with the corneal surface and cover angular position from 0 degrees to 180 degrees.

3. **Hemimeridia:**

   They are also called semimeridia and are defined from the centre outwards and cover angular positions from 0 degrees to 360 degrees.

4. **Sagittal planes:**

   The sagittal planes or transverse planes complete the three dimension of the corneal structure. Its intersection at a surface point is perpendicular to the meridional plane through that point and contains the surface normal.

AXIS DISTANCE, SURFACE HEIGHT AND REFERENCE AXIS:

Axis distance:

It refers to the distance from a point on a curve to the reference axis along the surface normal at that point[3]. For a circle or sphere the axial distance and radii of curvature are all identical. Axial distance can be converted into a dioptric value for topographic interpretation. This can be done with the formula Da = (n-1)/d where Da is axial dioptres, d is axial distance, n and 1 are the indices of refraction of keratometry and air respectively. These axial distance based maps are useful for refractive power display in corneal topography.

Surface height:

It is the actual elevation of the corneal surface relative to a reference. The reference can be a plane tangent to the apex or a best-fit reference sphere. The surface height relative to a reference gives more clinical information in corneal topography. It determines the creation of colour coded maps. With reference to the surface height, an intermediate colour is chosen to depict the neutral position. Then the elevation above and below are graded accordingly.

Reference axis:

It defines the centre of topographic display and thus the meridional planes in which axial shape and curvature are determined. Depending on the type of application of corneal topography the axis appropriate for the centre can be selected.

CHARACTERISTICS OF CORNEA:

The geometrical and optical properties are some of the important characteristics of the cornea. The gross anatomy of the cornea is demonstrated by the geometrical property which is very basic. The concept of how light is refracted through the surface of the cornea is demonstrated by the optical property. It is an intrinsic property. Among the geometrical properties of the cornea, the diameter and thickness of the cornea are considered the most important.

The depth of ablation to be covered by an excimer laser during a refractive surgery can be calculated from a theoretical formula called the Munnerlyn formula[4] which was discovered by Charles Munnerlyn. The formula states that the depth of ablation (in micrometres) per dioptre of refractive change is equal to the square of the diameter of the optical zone measured in millimeters, divided by three[4].

For example to change the refraction of cornea by 4 dioptres in an optical zone of 3 mm, the depth of ablation required would be 12 micrometers. To change the refraction by the same 4 dioptres in an optical zone of 6 mm, the depth of ablation required would be around 48 micrometers. This is because the ablation depth is directly proportional to the square of the optical zone.

It is to be noted that the depth of ablation will not take into account the transition zone of surgery. Hence the actual depth of ablation and surface of the cornea will be slightly different as when compared to the theoretical Munnerlyn formula[4]. The surgery is also influenced by many other factors like the sex, age and race of the patient. Even factors like the barometric pressure and ambient humidity will change the required depth of ablation slightly.

The important optical properties of the cornea include the curvature and the angle kappa[4]. The amount of corneal astigmatism is determined by the curvature. Angle kappa is the angle formed between the visual axis and the anatomic pupillary axis of the eye. The measurement of this angle can be made by Hirschberg test. This test is based on the location of the corneal light reflex. Because of the temporal displacement of the fovea from the pupillary axis, the corneal reflex falls around 0.5 mm nasal to the center of the cornea. The Hirschberg test is considered to be positive if the corneal reflex does not fall on this location. The Orbscan topography can measure the location of corneal reflex exactly in relation to the x-y axis.

There must be knowledge of the normal findings of the cornea in order to detect any abnormality. Depending on factors like the age and race of the population, the normal corneal characteristics actually vary from one another. Any finding which falls out of the normal range requires caution and misinterpreting it can lead to grave complications.

The curvature of the corneal anterior and posterior surfaces can be expressed as radii of curvature in millimeters. This is expressed clinically in keratometric dioptres. The shape of the anterior surface and posterior surface can also be shown in micrometers as the elevation of the actual surface relative to a chosen reference surface for example, a sphere. The overall shape and major irregularities of the surface of the cornea such as the corneal astigmatism are characterized by these two concepts. The corneal power is expressed as refraction in terms of dioptres. It is an optical property and depends on the surface shapes and the refractive index of the surface[10].

The keratometric dioptre is based on derivations form keratometry. It is calculated from the radii of curvature as given below:

K = Refractive index of 337.5 / Radius of curvature.

This derivation is a simplified way and ignores the fact that the air-tear interface is the refracting surface. It does not take into account the oblique incidence of incoming light in the periphery of the cornea. Therefore it performs a miscalculation of a true corneal refractive index of 1.376 to 1.3375 in order to correct the above factors. Hence to differentiate from the dioptres depicting the true refractive power at a certain corneal point, these dioptres are called as the keratometric dioptres.

CORNEAL TOPOGRAPHY

The word “topography” is a general term in geography derived from the Greek language – “to place” (topo) and “to write” (graphein). Its meaning is to describe a place. Corneal topography refers to the study of the shape of the corneal surface and gives a graphic representation of its geometrical properties[6, 8]. This measurement of the shape, refractive power and corneal thickness is very important to diagnose corneal disorders so that the appropriate method of vision correction can be planned.

Historically the study of corneal topography started in the sixteenth century[8]. The anatomy of the eye was first accurately described by Scheiner in 1619. He described the curvature of the cornea using glass balls having different types of curvatures. Since then different and better corneal description tools have been developed in pursuit of the ideal individualistic corneal models.

METHODS OF CORNEAL TOPOGRAPHIC ANALYSIS

The various techniques[8, 40] that have been employed to study the corneal curvature are as follows:

1. KERATOMETRY:

In 1728, the ophthalmometer was invented by Pourfour de Petit. This device was used for measurement of the eye dimensions. Later

Helmholtz and Javal modified the device in order to specifically measure the curvature of the anterior corneal surface. This device was termed keratometer which is in fact the trade name of Bausch & Lomb.

The principle of keratometry is essential for corneal topographic analysis. Along the orthogonal meridia of the anterior corneal surface two pairs of fixed points are reflected in the paracentral zone. They are separated by 3mm approximately. The measured distance between these two pairs is used by keratometry. The device projects an illuminated target on the surface of the cornea from a distance fixed based on the focus and alignment. By comparing the diameters which are measured on the calibration spheres the maximum and minimum diameters of the reflected images can be determined. These measurements provide the radius of curvature of the central cornea and also the amount and axis of any astigmatism if it is present.

Keratometry is routinely used in contact lens fitting and in preoperative calculation of intraocular lens power to visually rehabilitate an aphakic eye. It is reasonably reliable for the accurate measurement of corneal contours.

Limitations:

- It provides no useful data of the surface of the cornea which is in the central or peripheral zones.

- The keratometer assumes that the cornea is a sphere or spherocylinder. But the normal cornea is often aspheric and asymmetrical and hence keratometer cannot be used to accurately measure corneas that are different from a sphere or spherocylinder.

2. KERATOSCOPY:

The evaluation of topographic abnormalities of the surface of the cornea by direct observation of images of mires reflected from the corneal surface is called keratoscopy. It covers about 70% of the anterior surface of the cornea. It has evolved into three types:

a) Placido disc keratoscope:

It was first developed by Antonio Placido in 1880. It is popularly called as Placido disc. It consists of equally spaced alternating black and white rings with a hole in the centre. The patient's cornea is observed through the hole. Any deviations from evenly spaced concentric circles indicate distortions in the shape of the cornea. It is only a gross method of qualitative evaluation of the shape of the cornea.

Limitaitons:

- Small degrees of abnormalities in corneal shape are not easily distinguished.

- It cannot be used when there is non-reflection of the target by the cornea as in corneal epithelial defects or opacities.

b) Photokeratoscopy:

When a photographic film camera is attached to a keratoscope it is called photokeratoscope. A record or portrayal of corneal surface produced by the photographic film is called a keratograph. In 1896 Gullstrand provided precise methods for quantitative analysis. In this technique, keratoscopic image is photographed and the size of the images on the photographic film can be varied to change the size of the corneal image. The corneal curvature is then measured using the distance of the keratoscopic rings from the cornea, the magnification of the virtual image formed by the anterior corneal surface and the focal length of the objective of the camera.

The images of most photokeratoscopic rings cover the paracentral zone with overlapping of the central and peripheral zones. Therefore the optically important central 2 to 3 mm zone is not covered. In the photographs if the lines are closer it indicates a steeper cornea and if the lines are further apart it indicates a flatter cornea. However corneal cylinders upto 3 D can be missed by this technique.

c) Videokeratoscopy:

When a television camera is attached to a keratoscope it is called a videokeratoscope. It has been computerized in recent times.

3. CORNEAL TOPOGRAPHY SYSTEMS:

Corneal topography system or videokeratogarphy[40] implies computerised video assisted technique which provides detailed information of the shape of the corneal surface.

The basic unit of a corneal topographic system primarily consists of a projection device, video camera and a digital computer attached with a slit lamp chin rest.

a) Projection devices used in various systems include:

- Placido disc based devices
- Scanning slit beams
- Calibrated grid and
- Light wave interference fringes

b) Video camera:

The reflected images of rings projected onto the cornea are captured on charge-coupled device camera (CCD). The image accuracy and precision are dependent on focusing, decentration factors, shadows (artefacts) and proper acquisition of good images.

c) Computer:

The video camera is hooked up to a computer that generates a 'topographic map' of corneal curvature based on the measured distance between the rings reflected from the cornea. The accuracy of corneal curvature data processing depends a lot on the software editing features. After analysis the graphic picture of the patient's topography is displayed in various forms.

Corneal topographic system – Types:

Depending upon the projection device used for acquiring corneal shape information, different technologies of corneal topographic systems have been developed so far. They are:

i) Placido disc topography systems:

Here a Placido disc based projection device is used. Historically the Placido disc based systems were the first to be developed and thus are the most widely used and understood. Most placido disc based systems project around 8-32 concentric rings on the cornea. The rings are numbered from inside out. A specified ring in different instruments may cover different areas. Therefore it is important to mention the diameter of the projected ring along with the number. The virtual images of these reflected images are located anterior to the iris.

Limitaions:

- Data from the central zone has to be interpolated even though this unmeasured central zone is very small in some devices.
- As the images are obatained from the light rays reflected off the tear film, the quality of tear film is very important
- When mapping aspherical or irregular surfaces the data is less accurate because of assumption of sufficient smoothness in the radial direction used.

Commercially available Placido disc topography systems are:

LSCUTS:

LSCUTS projects 11 rings with 1980 mire coordinates for corneal imaging. It displays four basic types of diagrams showing raw keratoscopic data, three dimensional wire model of corneal surface power distribution, dioptric point surface power and colour coded contour map of corneal surface power[6].

CMS:

It is actually a videokeratographic technique in which the keratographs are recorded with the help of a video recorder. It has 32 rings covering the cornea from the apex to the limbus. Optical cross sections of the cornea can also be obtained by adding a slit lamp with dual beam scanning laser. A typical analysis usually uses 14 optical cross-sections with 1400 data points. The representation of geometrical functions of the front and back surface of the cornea is generated in this technique. Topography along with pachymetry can be obtained with attachments of CMS. The determination of axis and power of corneal cylinders can be done with the help of algorithms. Simulated K value, surface asymmetry index and surface irregularity index are few examples. These are considered to be good predictors of best corrected visual acuity. Still they may also give false results if localized uniform power is present in an irregular cornea.

Computerized corneal topographer EH 270:

This has different video systems according to the requirements of the operating person. It has a magnification of up to 8 times depending on the zoom, a contour map of the cornea showing its whole surface, a view of contour-cross-section of the meridional cornea, astigmatism of any two chosen meridia, an overlay image of principal astigmatic axis on the cornea,three dimensional display, etc.

EyeSys 2000 Corneal analysis System:

This is a sixteen ring device which uses videokeratoscopy. The time taken for processing of image is very fast coming to about 3 seconds. 6000 to 6500 points of data are analysed and map plots depicting contour with codes of colour are also included. The software considers the Stiles-

Crawford effect and permits display of light entering the pupil with relation to its brightness. This gives more practical information which could be useful for analysis.

TMS-1 Topographic Modelling System:

This utilizes 31 projected rings thereby giving 7000 data points. The coverage of cornea is 0.02 to 11 mm. The accuracy is 0.1 D. This system has a patent for accuracy of alignment of laser thus gaining the advantage of an individualized plan for programming any refractive surgery.

ii) Slit imaging topography systems:

This system uses scanning slits over the cornea to get information on topography. It uses a similar principle as that of a slit lamp. It uses two slits which are positioned at 45 degrees against both the sides of the axis of the instrument. From each direction 20 slit images are captured with an overlap of 7 mm diameter in the central area. Based on the individual corneal shape, a total of upto 10 mm of the cornea can be covered. Within an approximate time of 15 seconds all the images can be captured. The main advantage is that all surfaces of anterior segment can be measured.

Limitations:

- The time taken for scanning is relatively longer coming to about 1.2 to 1.5 seconds.
- For measuring the posterior cornea there is no establishment of clinical accuracy
- Information regarding the repeatability and accuracy of Pentacam has not been found yet.

Commercially available Slit imaging topography systems:

Orbscan:

It uses optical beam scanning which is extended from slit lamp corneal topography. A localized impression of the surface profile is obtained using an image formed by a slit of light which intersects the cornea. To get the impression in an area much wider, multiple images of this slit projected at various positions are used. The anterior surface of the cornea is digitally captured and the posterior surface of the cornea is also measured separately. Therefore the thickness of the cornea described as the distance between the anterior and posterior surface can be determined for any point on the cornea.

Orbscan II, an improvement of the basic model is considered to be one of the best available topography systems. It incorporates the slit scanning along with a placido disc system of advanced model to give an added advantage.

Pentacam:

This captures the image of the anterior segment of the eye with the help of a rotating Scheimpflug camera. The pictures captured in each dimension of the anterior segment are displayed by the rotation process. The topography of the anterior surface of cornea, posterior surface of cornea, the anterior axis and the surface of the anterior lens are then constructed using the captured images.

4. DIGITAL RASTERSTEREOGRAPHY:

This technique utilizes a direct image on the surface of the cornea. A calibrated grid is projected and photographed. The pattern of the grid is such that the horizontal lines and vertical lines are spaced at a distance of 0.2mm apart. The cornea and tear film are stained with fluorescein before capturing the image. The pictures are analysed using computer algorithms. For an approximate diameter of 7mm the system has an accuracy of about 0.3D. Even though the contour plots of the cornea look like keratographs, each line is in fact an isopter. Each isopter represents areas of equal height of the surface of the cornea. PAR CTS is one of the popular techniques which incorporates this system.

Advantages:

- This technique analyses the whole corneal surface along with a part of the sclera thus giving more information than keratoscopy.
- The interference caused by surface of the cornea or any defects in the stroma does not affect the projection of images.

5. LASER INTERFEROMETRY:

The property of interference of light waves is used in this method. The fringes of interference are used to cover the whole anterior surface of the eye and then measurements are recorded. Both holography and Moire fringe analysis can be incorporated. But clinically this technique is not very much used or popular.

Corneal Lens Analysis System (CLAS) is one of the commercially available systems using laser holographic interferometry. It uses an object and reference beam which are not split but have oscillations of the same frequency and are in phase with each other. This readily decreases the effects of vibration. The measurement of optical path difference gives an analysis of optical aberrations which are reflected from the surface.

DISPLAY OF TOPOGRAPHIC DATA

The various forms of display of the corneal topography are:

1. NUMERICAL POWER PLOTS:

It depicts the curvature of the cornea of specific areas in dioptre values. It uses 10 concentric circles having an interval of 1mm between them to display the data. The numerical values are depicted in various colours which are standardised with a colour scale. The numerical plot also depicts the average dioptric values of all the 10 zones formed by the concentric circles. The average of the overall curvature of the cornea is also depicted.

2. KERATOMETRIC VIEW:

It shows the keratometric readings of two principal meridia K1 and K2. It is taken from three different zones at the same point of time. The zones included are - the central zone of 3 mm, the intermediate zone of 3 to 5 mm and the peripheral zone of 5 to 7mm.

The skewing of semi-meridia can be assessed with this map. The corneal astigmatism is said to be irregular or non-orthogonal if the keratometric readings in the principal meridia deviate more from its normal alignment of being perpendicular to each other.

3. PHOTOKERATOSCOPIC VIEW:

It shows the original black and white photographs captured by the video camera using the Placido disc. This map is helpful for the confirmation of proper fixation by the patient and also in identification of the eye which was captured. The rings which are reflected on the cornea are placed more towards the side of the limbus than of the other side. Also the distance in between each ring is narrower on the nasal side compared to the temporal side.

4. PAR CTS PROFILE VIEW:

This is a graphical view. The steepest and flattest meridia of the corneal surface are taken and a graph is plotted along its XY axis. The difference is showed in dioptric value. The display button depicts the difference of astigmatism between the meridia which are flat and steep. This difference plot also has a grey zone which indicates the pupillary area. It is traced across the grey band as a straight line in cases of symmetrical eyes. If astigmatism is present it shows an apparent slag. If the increase of this slag is more it indicates the cornea has more asymmetry.

5. COLOUR CODED TOPOGRAPHIC MAP:

These are the commonly used form of display in topographic analysis. Two parameters are considered for the interpretation of these contour maps:

a) Colour codes

b) Scales for different ranges

a) Colour codes:

The intensity of colours is relative and should be interpreted based on the areas analysed. However generally they are classified into two types:

i) Hot colours: They are indicated as red and its various hues which usually represent the areas of the cornea which are steep.

ii) Cool colours: They are indicated as blue and its various hues which usually represent the areas of the cornea which are flat.

The progressive decrease in refractive power is denoted by the following order of colours: Red-orange-yellow-green-purple-blue.

b) Scales for different ranges:

For interpretation of a colour map, we should always know the scale used. Based on the scales used, two seemingly similar colour maps may denote two totally different corneas. The two popularly used scales are:

i) **Absolute scale:**

Here each colour depicts a 1 D interval for the values from 35 D to 50 D. Colours for the values which are above and below this range are depicted as 5 D intervals. For routine uses like preoperative screening this scale is useful. The main limitation is that subtle changes in the curvature of the cornea are not shown thereby leading to failure in detection of cases like early keratoconus.

ii) **Normalized scale:**

Here depending on the total dioptric power of the eye the cornea is classified into 11 equal colours. This helps in depicting even minute topographic details of a specific cornea. It gives more detailed information of the corneal surface than the absolute scale. The main limitation is that comparison of two different maps cannot be done directly based on the colour thereby making us to rely on keratometric values of the different scales which are used.

QUANTITATIVE INDICES

With the help of corneal topography few quantitative indices can also be generated like:

- Predicted visual acuity depending on the shape of the cornea
- Surface regularity index
- Simulated keratometric readings (Sim K)
- Minimum keratometry reading
- Point spread function
- Surface asymmetry index

Simulated keratometric readings:

The curvatures of the cornea in the central 3 mm are characterised by these readings. The simulated maximum K reading is the keratometric value of the steepest meridian of the central 3 mm area of the cornea. The simulated minimum K reading is the keratometric value of the flattest meridian of the central 3 mm area of the cornea. Both the readings are taken at right angles to each other.

Surface asymmetry index:

There is a change in curvature of the cornea when we move from the centre to the periphery. This amount of change is indicated by the index of asphericity. A cornea which is normal is prolate. It has an asphericity with a

Q of -0.26. The Q value is negative for a prolate surface and positive for an oblate surface.

DISPLAY FORMATS OF COLOUR MAPS

1. **CORNEAL POWER MAP(SAGITTAL OR AXIAL):**

    Here the dioptric power of different points on the cornea is represented in 24 colours. For each image of placido ring formed from the centre to vertex, the radius of curvature is calculated 360 times. The sagittal algorithm takes the average of the data points from the first ring to the next ring and subsequently.

2. **TANGENTIAL MAP:**

    When compared to the axial map the geographical data of the cornea is better represented in this map. From the centre vertex, tangents are projected outwards all over 360 degrees. The ring curvature is calculated along the tangent or ring intersection. This is also called as instantaneous curvature map. It is the best indicator of the shape of the cornea but it is a poor indicator for power of the cornea. Hence the values from the tangential map should never be used for deriving K values. For diagnosing corneal ectatic conditions like keratoconus this map is very accurate.

3. ELEVATION MAP:

Elevation cannot be measured directly with placido disc topography, but certain inferences help in constructing the elevation maps[27]. The elevation of a point on the surface of the cornea is displayed as the height of the point on the surface of the cornea relative to a spherical reference surface[29]. Most instruments use the sphere as a reference sphere. For every elevation map, a best fit sphere is calculated separately by the instrument software. It is based on the best mathematical approximation to the original surface of the cornea. When the maps are plotted for different reference surfaces, the same surface may look different. Therefore it is not easy to compare two elevation surface maps which have different best fit spheres as reference values. This comparison can only be intuitive.

The elevation maps also help in individualising localized elevations caused due to projection from a cornea which has an otherwise steep area[21]. The areas above the reference sphere are depicted in hotter colours and the areas which are depressed than the reference sphere are depicted in cooler colours. The elevation maps are in fact measurements of the difference.

For laser refractive surgery which removes tissue from the surface of the cornea in order to change the refractive power, these elevation maps give more relevant data for calculating the depth of ablation and optical zones.

4. REFRACTIVE POWER MAP:

This map is actually a modification of the standard map formed by including the effects of spherical aberrations also. The refraction of the light by the corneal surface in true dioptres of power is illustrated by this map. The calculations are performed using ray tracings and Snellen's law of optics.

In this map a cornea which is spherical will have cooler colours in the centre and hotter colours in increasing intensity extending out to the periphery. Hence the refractive map can also be called as the asphericity map of the cornea. It is very helpful in determination of the optical zone for fitting of gas permeable lenses and also for planning refractive corneal surgery.

5. **IRREGULARITY MAP:**

This depicts the corneal areas with hot colours. With the use of previous elevation map results in relation to toric reference, the distortion of cornea is displayed in this map. The higher values of distortion are measured in units of wavefront error and represented in hotter colours. The wavefront number is converted to dioptre of distorted power and called as spectacle blur. This map helps to quickly assess if the cornea is the cause of poor visual acuity. The acuity is said to be compromised if a significant hot colour is present inside the pupil zone.

6. **TREND AND TIME DISPLAY:**

This map displays the topographic changes of the cornea with time or postoperatively. They are displayed in chronological order.

7. **DIFFERENCE DISPLAY MAP:**

It shows the comparative difference of any two specific corneal topographic maps.

8. **RIGHT EYE/ LEFT EYE (OD/OS) COMPARE MAP:**

This map permits comparison of both the right and left eyes simultaneously.

CLINICAL USES OF CORNEAL TOPOGRAPHY

1. DIAGNOSIS OF CORNEAL DISEASES:

Corneal topography plays an important role in diagnosing conditions subclinically. Few examples include keratoconus, terrien's marginal degeneration, epitheliopathies and corneal epithelial dystrophies, pellucid marginal degeneration.

2. CONTACT LENSES:

Corneal topographic analysis is helpful for comfortable fitting of contact lens especially in cases of rigid contact lenses. In difficult cases like keratoconus, post-keratoplasty, post-radial keratotomy and irregular astigmatism the topographic data aids the fitting.

Contact lens induced changes of the cornea like corneal warpage, central irregular astigmatism and loss of radial symmetry can be diagnosed early with topography. These changes are mostly reversible with the stopping of use of contact lens.

In order to verify complex contact lens specifications the doctor and contact lens manufacturer can utilize the topographic data.

3. KERATOCONUS:

The diagnosis of keratoconus has been revolutionised by corneal topography[37]. It detects the subclinical changes of the cornea very easily before the manifestation of slit lamp findings. Keratoconus was initially believed to have either of two shapes – the oval type or the nipple type. But after the use of this technique it has been found that the shapes are in fact more complex[28, 30, 37].

Contact lens fitting in keratoconus has also become much easier with the study of topographic data.

A mild form of keratoconus without any manifestation of clinical signs has been demonstrated by videokeratographic analysis in the family members of patients affected. This was also named as Forme Fruste by Amsler[38].

4. RADIAL KERATOTOMIES:

The mechanics of radial keratotomies are better understood when the cornea is evaluated both pre-operatively and post-operatively.

The pre-operative topographic data has revealed that corneas having the same central curvature as derived from a keratometer, have in fact markedly different shapes altogether by exhibiting a prolate, oblate or spherical shape.

The post-operative topographic data has revealed that the entire cornea is flattened with only a relative steepening of the periphery.

Repeat radial keratotomies and contact lens fitting post-surgery can be considered with the help of topographic data.

5. POST-KERATOPLASTY ASTIGMATISM:

With the facilitation of corneal topography, tight sutures can be removed to control the astigmatism in post penetrating keratoplasties. Earlier corneal relaxing incisions were placed at the graft-host interface. But now they can be placed at the steepest point of the steepest corneal meridian with the help of topographic data.

A typical teardrop image on corneal topography indicates an excessive flattening of the cornea because of wound gap. This helps in planning procedures to revise the wound or to perform wedge resection.

Contact lens fitting in post penetrating keratoplasty patients is better than that derived from keratometric findings.

6. PRK AND LASIK:

Corneal topography has become virtually indispensable in planning Photorefractive Keratectomy (PRK) and Laser-Assisted-In-Situ Keratomileusis (LASIK). It is not only required to screen the candidates for fitness but also in giving data about the ablation zone quality, the diameter of ablated zone, centration of the ablation and the stability of topographic alterations.

The desired dioptric change in the power of the cornea can be derived from differential topographic maps.

The post-operative glare or halo effects can be explained by the decentration of ablation zone which is detected in postoperative maps.

The decrease in visual acuity or the quality of vision post-operatively can often be explained by the irregular ablation zones which are seen in central islands. To prevent such occurrences, the procedures have been modified with the help of recognition of such zones.

7. OTHER USES:

With help of K value derived from corneal topography more accurate calculation of the IOL power can be done.

With corneal modelling systems which has a dual beam scanning laser slit lamp we can get Laser pachymetry for the thickness of the cornea.

Storage of the topographical analysis of the pre-operative and post-operative corneas can be used for self-study and patient's satisfaction.

DISADVANTAGES OF COMPUTERIZED CORNEAL TOPOGRAPHY

Some of the limitations of this advanced and evolving technique are:

1. The normal cornea being aspheric, the qualitative and quantitative interpretations may be erroneous as the algorithms for calculating power uses the concept of spherical optical systems.
2. Only when there are no areas of abrupt transition in the curvature of the cornea, there is validity in correlating the power and curvature of the cornea for spherical and elliptical surfaces.
3. The average of the data is taken along the meridia, which tends to enlarge the 'blend zones' rather than depict the sharp boundaries.
4. The formulae used for calculation of power are centred on the apex of the cornea and not based on the line of sight.
5. As the central corneal power is derived from central rings, it might overestimate the value in corneas which are oblate.
6. The original index of refraction of the cornea is 1.376. The keratometric index of refraction used is 1.3375. This can underestimate the change of corneal power post refractive surgeries.
7. There might not be a change in depiction of corneal topography in cases of unsuccessful PRK, even if a change in thickness of cornea had occurred.

ORBSCAN

The detailed description of the Orbscan is given by Hassan Hashemi et al[11]. The basic version of the Orbscan slit-scanning topography system was originally established in 1995. At that point of time it was the only popular and commercial system available to measure the corneal surface elevation and other characteristics. The placido disc technique was incorporated in the later versions and the system was called the Orbscan II. This addition enabled direct measurement of the curvature of the cornea. Other important variables like corneal thickness and anterior chamber depth are indirectly measured using this system.

First the basic information like the subject's name, age, sex and refraction details are entered. Then by adjusting the instrument, proper positioning of the subject's head, forehead and chin is done. From either side about 20 slits are projected onto the cornea throwing a total of 40 slits for the data acquisition. The slit projection is done in a fashion of scanning at an angle of 45 degrees. The light which scatters back is captured with the help of a digital video camera. From each slit data is extracted from 240 points. This data is then processed by the system's software and the different variables are calculated accordingly[11].

The most common display of the Orbscan II is the "Quadmap"[11]. This includes the the elevation of the anterior and posterior corneal surface in a two-dimensional colour coded format maps, the corneal thickness or the pachymetry map and the corneal curvature or power map. In display, the four maps when read from top left in a clockwise manner will indicate the anterior elevation, posterior elevation, pachymetry and axial power.

There is a gray box in the top middle area which displays the best fit sphere diameter and power of their adjacent map, the elevation reading, meridian and radius at the point where the cursor is placed[11].

There is a middle gray box from the top which displays the subject's name and identification number, the exam date and simulated keratometry readings. It is followed by the irregularity index value and power data of the 3 mm and 5 mm diameter zones[11].

The bottom section gives the values of the corneal diameter, pupil diameter, location and amount of thinnest pachymetry of the cornea, the anterior chamber depth (ACD), and the angle kappa size and intercept[11].
There are two boxes in the bottom one on the right and the other on the left side. This displays the power of the cornea and the corneal thickness at the point where the cursor is placed[11].

Given below are some of the important variables which are commonly assessed for screening refractive surgery candidates:

Best fit sphere:

Just like in terrain topography where the elevation of any surface is surveyed with reference to sea level, the elevation of the corneal surface is also measured from a reference. But here the reference is not fixed. Even though the cornea does not have an ideal spherical shape, the reference surface most commonly used is a sphere. This sphere can be freely adjusted with regards to its diameter and position in order to fit the given surface of the cornea with a minimum square difference. This is called the floating best fit sphere (BFS).

In case of ectasia of the cornea, the earliest signs are presumed to occur in the posterior surface of the cornea. A value of more than 51 D of the posterior BFS has been suggested to indicate primary posterior corneal elevation. If it is more than 55 D it is considered to be a criterion in the diagnosis of Forme Fruste Keratoconus (FFKC). The ratio of radii of the anterior BFS to the posterior BFS below 1.23 is considered normal. A value between 1.23 and 1.26 can be regarded as keratoconus suspects and therefore have to be treated with caution. Any value above 1.26 is contraindicated for laser refractive surgery.

Surface elevation maps:

Orbscan gives the data for elevation of the anterior and posterior surfaces of the cornea and also of the anterior iris and anterior lens depending on how much penetration is allowed by the pupil. This information is displayed commonly in the two-dimensional colour coded map. In this map the points which are very close to the reference surface or the BFS are represented in green, the points which are above the BFS are represented in warmer colours and the areas which are below the BFS are represented in cooler colours.

In order to understand the structure and shape of any given cornea and to rule out abnormalities, it is important that the anterior elevation map and mainly the posterior elevation map are to be thoroughly studied first. The identification of abnormally elevated areas, or asymmetric patterns of corneal elevation such as inferior or inferotemporal deviation of the area of maximum elevation is significant. The choice of the colour scale and step size influences accuracy of these observations.

Tanabe et al[12] suggest using 10 and 20 microns interval colour scales on the anterior and posterior elevation maps respectively. According to Tanabe's recommendation any map is considered abnormal if it has more than three colours in the central 3 mm diameter zone.

We should also check the quantitative criteria like the mean anterior and posterior elevation readings.According to Rao et al[13], eyes classified as keratoconus suspects have a mean anterior elevation of 10 microns and a mean posterior elevation of 35 microns. In normal controls, the mean anterior elevation is 5 microns and the mean posterior elevation is 21 microns.

In eyes with keratoconus, the elevation of the posterior surface in the area of the cone is more than 40 microns. A posterior elevation of 40 microns or more is used to distinguish keratoconus and keratoconus suspects from the normal corneas. But Fam et al[14] showed that this criteria has a sensitivity of 57.7% and a specificity of 89.9%. Hence it was suggested that instead of posterior elevation the anterior corneal parameters have to be used.

Finally it has been agreed that an anterior elevation ratio expressed as anterior elevation / anterior BFS can be taken. The value should be 0.5122 or less.

Orbscan also allows studying the changes in the cornea after refractive surgery. It has a feature which makes it possible to compare two maps. It can give a difference display which is obtained by subtracting the data on corresponding points and finally plotting them on a separate map[11].

After laser refractive surgeries the largest amount of change of anterior elevation appears in the center for myopia and in the peripheral zones of treatment for hyperopia. Studies with Orbscan in the posterior surface of the cornea have shown that there are significant levels of posterior bulging or a forward shift post-surgery. Earlier this was thought to be an imminent sign of ectasia. But further studies have proven that this observation is an artifact, thought to be produced due to changes in the magnifying effect of the cornea.

Corneal thickness:

Another alluring feature which made the Orbscan much more popular is the pachymetry map of the whole corneal surface. The data is generally displayed in a colour coded map. The normal ranges of corneal thickness are represented in green and the thinner areas of the cornea are represented in warm colours. Alarmingly thin areas are displayed in red. To provide a quick view, the bottom right map display depicts numerical values in 5 points which include the center of the cornea, and the superior, inferior, nasal and temporal points 3 mm from the center. The thinnest point of the cornea and its site of location with relation to the center is shown in the central box of the map.

The ultrasound pachymetry[42] is obtained by placing the probe at right angles in contact with the surface of the cornea. The thickness is measured in only one point with each contact. It is user dependent and has a risk of infection. These limitations are overcome by Orbscan. However initial studies showed significant differences between the readings by ultrasound and Orbscan.

In order to convert the Orbscan readings into the ultrasound pachymetric equivalents, an acoustic factor of 0.92 was recommended to be used by the manufacturer but various other equations were also proposed by researchers[42]. Further research showed that Orbscan has the tendency to overestimate the corneal thickness readings in thicker corneas and underestimate in corneas which are thin, thereby indicating that a single equation is not sufficient[42].

As the corneal thickness is derived from the difference of elevation between the anterior and posterior surface of the cornea, the postoperative artifacts in the posterior elevation maps could make the pachymetry readings more inaccurate after refractive surgery.

Corneal curvature and power:

The corneal power map when displayed in a Placido based format is considered to be the most familiar for examination of an Orbscan quadmap. The measurements of the curvature of cornea on calibrated test surfaces, normal subjects and post refractive surgery cases have been tested for accuracy by various studies. These studies show that the measurement of the anterior and posterior surfaces of the cornea by Orbscan is fairly accurate in cases of normal eyes. This implies that the criteria used for the traditional topography systems can be applied to Orbscan.

Orbscan also displays the mean, astigmatic and optical power map in addition to the traditional axial and tangential corneal power maps. These options can be compared and presented separately. The determination of corneal power after laser refractive surgery can be done by various methods and data obtained from Orbscan. The 4 mm central zone of the total optical power map is recommended for this purpose by various studies. Still some studies[11] show that the measurements of corneal curvature by Orbscan, especially of the posterior surface of the cornea are not accurate in eyes which have undergone refractive surgery.

The average curvature is measured at each point on the surface of the cornea for the mean power map. It is free of any bias which could occur with measurements of the axial and tangential curvatures. Each point is defined individually. Hence it can display the true location of anomalies of the surface like the cone in cases of keratoconus.

Corneal irregularity:

The corneal irregularity index is displayed in the center box of the Orbscan quadmap. The corneal irregularity indices in the 3 and 5 mm diameter zones are directly proportional to the standard deviation of the curvature of the surface. This is calculated by the Orbscan using an algorithm. The irregularity is usually correlated with loss of best corrected vision which is unable to be corrected by any sphero-cylindrical correction. Therefore this index is important for screening purposes. The indices are found to be strongly associated with the maximum keratometry readings. The cornea is supposed to have an irregular astigmatism or higher order aberration if the values of the index are high. A value more than 1.5 D for the 3 mm diameter zone and a value more than 2.5 D in the 5 mm diameter zone could indicate keratoconus. But it is always used only in conjunction with the other findings.

Hence, the Orbscan boasts a user friendly software. We can be confident of the information derived from Orbscan of the preoperative screening tests and from corneas of other ocular conditions. However any postoperative data needs to be considered with some amount of caution.

REVIEW OF LITERATURE

Wilson and Klyce[15] conducted a study on screening for corneal topographic abnormalities before refractive surgery. The corneal topographies of patients with myopia who sought refractive surgery were evaluated. The study analyzed both eyes of 53 patients with a topographic modeling system.

It was found that 35 eyes (33%) of the 106 eyes had abnormal topography. 32 eyes (38%) out of 84 eyes with contact lens wear had irregular astigmatism, loss of radial symmetry or absence of the normal progressive flattening from the center to the periphery of the cornea. These changes were consistent with contact lens induced corneal warpage. In cases of rigid contact lens use, the changes were found to be more severe and also of increased frequency. Around 3 patients (5.7%) had definite keratoconus.

The study showed that the abnormal topographic characteristics in most of the eyes could not have been picked up if only a visual inspection of the images formed by photokeratoscopy had been followed.

Nesburn AB et al[16] used videokeratography to screen for subclinical corneal abnormalities in persons seeking photorefractive keratectomy. 146 apparently normal myopic eyes of 91 consecutive patients were included. In 6 patients (7 of 146 eyes), 2 had definite keratoconus, 3 were keratoconus suspects and 1 patient had early pellucid marginal degeneration.

David Varssanoet al[3] studied the prevalence of different topographic patterns in refractive surgery candidates and estimated the extent of rejection based on topography alone. They evaluated 200 eyes of hundred candidates which included 41 women and 59 men. The average age was 32 years. The topographic patterns were spherical in 36 eyes, spherocylindrical in 60 eyes, upper steep in 32 eyes, lower steep in 43 eyes, irregular astigmatism in 9 eyes, decentered in 3 eyes, suspected keratoconus in 11 eyes and probable keratoconus in 6 eyes. Around 27 eyes were rejected based on topography alone. 43 eyes with a lower steep pattern were difficult to be interpreted and were eventually rejected.

There were nine software calculated indices and the distinction between the spherocylindrical and the lower steep pattern was made by a keratoconus index. It was found that more than one half of the corneal topographies of the refractive surgery candidates did not correlate with the spherical or spherocylindrical patterns which were presumed to be normal.

Renato Ambrosio et al[18] reviewed the incidence of corneal abnormalities which were detected in a preoperative screening for Laser in situ keratomileusis (LASIK) or photorefractive keratectomy (PRK). It was found that from a total of 1392 refractive candidates 18 patients were rejected for LASIK or PRK based on corneal topography and/or pachymetry. 13 patients were found to have keratoconus or keratoconus suspicion or pellucid marginal degeneration and 5 patients were found to have thin corneas (<490 microns) in spite of exhibiting normal topography maps.

Li Lim et al[17] evaluated the corneal topographic patterns by Orbscan II and TMS -2N in 116 Asian patients having keratoconus. The control group had 70 LASIK candidates with myopia. A total of 196 eyes were analysed and the majority of eyes with keratoconus (71.2%) and keratoconus suspect (70%) had asymmetric bowtie patterns. It was also found that the eyes in the keratoconus suspect group had higher mean posterior elevation (46 +/-17 microns), 3 mm irregularity (2.44 +/- 1.36 diopters [D]) and 5 mm irregularity (2.61 +/-1.19 D) and thinner corneas (mean 504.4 +/- 40.4 microns). The normal eyes had a lower mean posterior elevation (26+/- 8 microns), 3 mm irregularity (1.05 +/- 0.37 D), 5 mm irregularity (1.38 +/- 0.39 D), and thicker corneas (554 +/- 25 microns). Moreover Orbscan II was concluded to be more sensitive than TMS – 2N in the screening of keratoconus.

Baris Sonmez[19] et al identified morphologic topographic parameters using scanning slit beam topography which helps in differentiating normal from keratoconic corneal characteristics. They retrospectively reviewed 207 normal patients who came for refractive surgery along with 42 eyes exhibiting clinical keratoconus.

A significant difference among the two groups ($P < 0.001$) was found for the 3mm irregularity index, 5 mm irregularity index, maximum posterior elevation magnitude, thinnest optical pachymetry magnitude, anterior elevation best fit sphere (ABFS), posterior elevation best fit sphere (PBFS), ABFS to PBFS ratio, the difference between the average inferior and average superior K values at 3 mm and 5 mm in both keratometric and tangential topographic maps and skewed radial axis at 3 mm and 5 mm of the keratometric topography map.

The skewing of radial axis at 3 mm, the magnitude of thinnest pachymetry and the irregularity index at 3 mm in the keratoconic group and the average of inferior and average of superior K value at 5 mm in the keratometric map, amount of astigmatism and maximum posterior elevation magnitude in the normal group were the least corrected parameters. It depicted that these parameters which are obtained using slit beam topography showed an improvement to differentiate keratoconic from normal corneal shapes.

Schor et al[20] did a clinical follow up of PRK and LASIK in eyes with preoperative abnormal corneal topographies. 84 eyes which had topographic abnormalities preceding PRK or LASIK were compared with 84 spherical equivalent paired normal eyes. The topographic characteristics which were abnormal preoperatively were apex displacement, increased asphericity, meridional irregularity, increased inferior superior asymmetry, increased curvature and combined features. The patients were followed up for a period of 6 months.

It was found that there was a significant loss of best corrected visual acuity in the apex displacement ($p<0.001$), combined features ($p<0.05$) and increased asphericity ($p<0.001$) patients. Postoperatively the number of eyes which had plus or minus 1 D of the surgical plan was found to be similar in all groups. It was concluded that even if the predictability of results were similar, there might still be a loss of vision if PRK and LASIK were performed in corneas having topographic abnormalities.

Zuzana Schlegel et al[21] did a study to compare the elevation maps of the anterior and posterior corneal surfaces between keratoconus-suspect eyes and normal eyes. 60 normal myopic patients and 48 keratoconus suspect patients were included. The parameters which were analyzed included the radii of anterior and posterior best fit sphere, central and thinnest corneal pachymetries, the aconic radius, aconic sphericity and aconic toricity of the anterior and posterior surfaces, the elevation of the anterior and posterior surfaces in the 1 mm radius zone. The elevation and aconic shape parameters of the anterior and posterior surfaces were compared and correlated.

It was found that the keratoconus suspect eyes had significantly lower mean central and thinnest pachymetry values ($p<0.001$). They also had significantly increased anterior toricity ($p=0.0002$) and posterior toricity ($p<0.0001$), much negative asphericity ($p=0.042$) and higher posterior elevation ($p<0.0001$). The keratoconus suspect eyes had better correlation between aconic toricity and the anterior and posterior corneal surfaces when compared to the normal eyes. However the normal eyes had a better correlation with aconic asphericity and apical curvature as when compared to the keratoconus suspect eyes. Among the keratoconus suspect eyes, the values for the posterior corneal elevation and the corneal pachymetry were different.

Sanjay N. Rao et al[13] studied the role of Orbscan II in the screening of keratoconus suspects before corneal refractive surgery.60 consecutive eyes which had suspicious videokeratography and a control group of 50 consecutive eyes without any suspicious features of videokeratography were evaluated before undergoing LASIK surgery. The Rabinowitz and Klyce/Maeda methods were used in the screening programs.

It was found that the mean anterior and mean posterior elevations in the groups testing positive for keratoconus were significantly different based on statistics when compared to the normal control group. In patients who satisfied both the Rabinowitz and Klyce/Maeda criteria for keratoconus , the mean posterior elevation was 44 +/- 2.5 microns whereas in the control group the mean posterior elevation was 21 +/- 0.6 microns. No statistical difference was found between the control and keratoconus suspect groups in the case of mean thinnest pachymetry. It was concluded that Orbscan II topography system if used in combination with videokeratography might help to identify patients who are at high risk for developing ectasia after LASIK.

Bina John et al[22] studied the corneal topographic characteristics of normal Indian eyes. The study included 216 patients in the age group of 10 to 80 years with a refractive error of range +2 to -2 D. The mean pachymetry at the pupil center was found to be 534.21 microns whereas at the corneal apex it was 535.1. The thinnest pachymetry was 531.1 microns.

The most common location of the thinnest pachymetry was in the inferotemporal quadrant (77.8%) followed by superotemporal (8.8%), temporal (5%), inferior (4.2%) and inferonasal (2.8%). The island was the most common anterior elevation pattern (41.9%), followed by the irregular ridge (39.5%), the incomplete ridge (17.7%) and the unclassified pattern (0.9%). The most commonly observed pattern in the posterior elevation map was the irregular ridge (51.2%), followed by the incomplete ridge (40.9%), the island pattern (7%), and the unclassified pattern (0.9%). The regular ridge pattern was found in neither the anterior nor posterior elevation maps.

The anterior sagittal topography with the green bin showed round pattern in 147 corneas (68%), oval in 8 corneas (3.7%), kidney shaped in 39 corneas (18%) and tear drop shaped in 5 corneas (2.3%). There were no symmetric or asymmetric bow ties. When the central yellow colours were used as pattern frequency, asymmetric bow tie was seen in 95 corneas (44%), tear shape was seen in 33 corneas (15.3%) and symmetric bow tie was seen in 31 corneas. It was also found that the number of patients having symmetric and asymmetric bow tie types declined as age advanced.

Zuguo Liu et al[23] did a study on normal eyes to evaluate the corneal thickness, anterior and posterior surface elevation and axial curvature of the cornea using Orbscan topography system. 94 eyes of 51 normal subjects were studied and it was found that the thinnest point of the cornea was located at an average of 0.90 mm (SD 0.51) from visual axis. The mean corneal thickness was 0.55 mm (0.03). The thinnest point of the cornea was located most commonly in the inferotemporal quadrant in 69.5% of eyes, followed by the superotemporal quadrant in 23.9%, the inferonasal quadrant in 4.3% and the superonasal quadrant in 2.1%. The lowest average thickness of 0.56 mm (0.03) was seen in the central cornea out of the nine regions of the cornea evaluated. The regions included central, superotemporal, temporal, inferotemporal, inferior, inferonasal, nasal, superonasal, and superior. The highest average thickness of 0.64 mm (0.03) was seen in the superior cornea.

The mean simulated keratometry (SimK) was 44.24 (1.61)/43.31 (1.66) dioptres (D) and the mean astigmatism was 0.90 (0.41) D. The most common elevation pattern seen in the anterior corneal surface was the island pattern (71.74%) followed by the incomplete ridge (19.57%), the regular ridge (4.34%), the irregular ridge (2.17%) and the unclassified pattern (2.17%). The most common elevation pattern seen in the posterior corneal surface was the island pattern (32.61%) followed by the regular ridge (30.43%), the incomplete ridge (23.91%) and the irregular ridge (13.04%). The most common axial power pattern of the anterior cornea was the symmetric bow tie (39.13%), followed by the oval type (26.07%), the asymmetric bow tie (23.91%), the round type (6.52%) and the irregular type (4.53%).

The study derived a new method for classification of the pachymetry maps and showed that an oval pattern was seen in 47.83% of eyes, a round pattern in 41.30% of eyes, a decentered oval pattern in 8.70% of eyes and a decentered round pattern in 2.18% of eyes.

Ho chang kim et al[24] studied the relationship between corneal astigmatism and keratometric patterns in 200 normal eyes and found that the mean corneal astigmatism was 0.32 D in round pattern, 0.63 D in oval, 0.43 D in irregular, 1.16 D in symmetric bowtie and 1.21 D in asymmetric bowtie pattern.

AIM AND OBJECTIVE

To evaluate the prevalence and correlation of various corneal topographic characteristics in clinically normal persons who were rejected for Laser refractive surgery based on Orbscan II (Bausch & Lomb) analysis.

STUDY DESIGN

A prospective, observational and descriptive study of persons screened by Orbscan II (Bausch & Lomb) for Laser refractive surgeries was designed.

INCLUSION CRITERIA

All persons who came to Aravind Eye Hospital, Madurai seeking Laser refractive surgery in the time perod from November, 2012 to May, 2013 were included in the study.

EXCLUSION CRITERIA

- Contact lens wear at or within 3 weeks of time of presentation
- Previous corneal or refractive surgeries.
- Corneal opacities
- Contact lens warpage

- Uncooperative persons
- Persons with normal corneal topography but having high refractive power with the corneal thickness being inadequate for laser ablation
- Persons rejected for reasons other than corneal topographic abnormalities:
  - Age less than 18 years
  - Unstable refraction for previous one year or longer
  - Presbyopia
  - Hypermetropia more than 4 Dioptres
  - Pregnancy and Lactation
  - Uncontrolled Diabetes mellitus and other immunocompromised disorders
  - Autoimmune and psychological disorders
  - Known case of ocular diseases like Herpetic keratitis, Glaucoma, Uveitis, Posterior segment pathologies and Dry eyes.

SAMPLE SIZE

From a total of 1518 persons who were found to be clinically fit for Laser refractive surgery in the time period allotted, around 144 persons were rejected based on Orbscan II (Bausch & Lomb) corneal topography analysis.

Out of these 144 persons, 10 persons had an abnormal Orbscan in only one of the fellow eyes and the other eye was normal. Hence the eyes with normal Orbscan were excluded and a total of 278 eyes were included in our study.

MATERIALS & METHODS

All persons opting for Laser refractive surgery were referred to the Cornea clinic for pre-operative examination. Relevant ophthalmic and medical history including history of contact lens wear was recorded. Subjective refraction, auto-refractometry and slit lamp biomicroscopy with undilated fundus examination were done. Schirmer's 1 test was done in all contact lens wearers and symptomatic patients to rule out dry eyes. Clinically normal persons were then subjected to Orbscan II (Bausch & Lomb) corneal topographic analysis.

The Orbscan was taken by an ophthalmic technician in the following manner. The persons were asked to place the chin on the system's chin rest and the forehead was secured with a strap. The persons were instructed to fixate on a blinking red light and the technician captured the image after aligning the cornea to the centre such that both half of the slits were clearly seen on the cornea. The captured images were saved for further evaluation.

After the Orbscan analysis, the persons underwent dilated subjective refraction and fundus examination. Then the Orbscan maps of all clinically normal persons were analysed and the persons rejected for Laser refractive surgery due to abnormal topographic characteristics were taken and recorded for our study.

The colour coded maps depicting the anterior and posterior surface elevations of the cornea were classified based on the PAR corneal topography system[26]. Accordingly the anterior elevation patterns were divided into regular ridge, irregular ridge, incomplete ridge, island, and unclassified patterns. The axial curvature of the anterior corneal surface of the abnormal maps were classified into round, oval, symmetric bow tie, asymmetric bow tie, and irregular patterns based on TMS-1 corneal topography system[25]. The pachymetric patterns were classified into round, oval, decentred round and decentred oval as described by Liu et al[23].

The thinnest point on the cornea was located based on the superior, nasal, inferior, temporal, superonasal, inferonasal, inferotemporal, superotemporal and central areas from the visual axis. The corneal thickness index (CTI) was defined as the ratio between the mean of the peripheral corneal thickness and the central corneal thickness.

The Orbscan criteria taken as risk factors for Laser refractive surgeries[10] in our study are as follows:

- Ratio of radii of Anterior BFS to Posterior BFS more than or equal to 1.23
- Power of Posterior BFS greater than 55 dioptres
- Keratometry reading greater than 47.2 dioptres

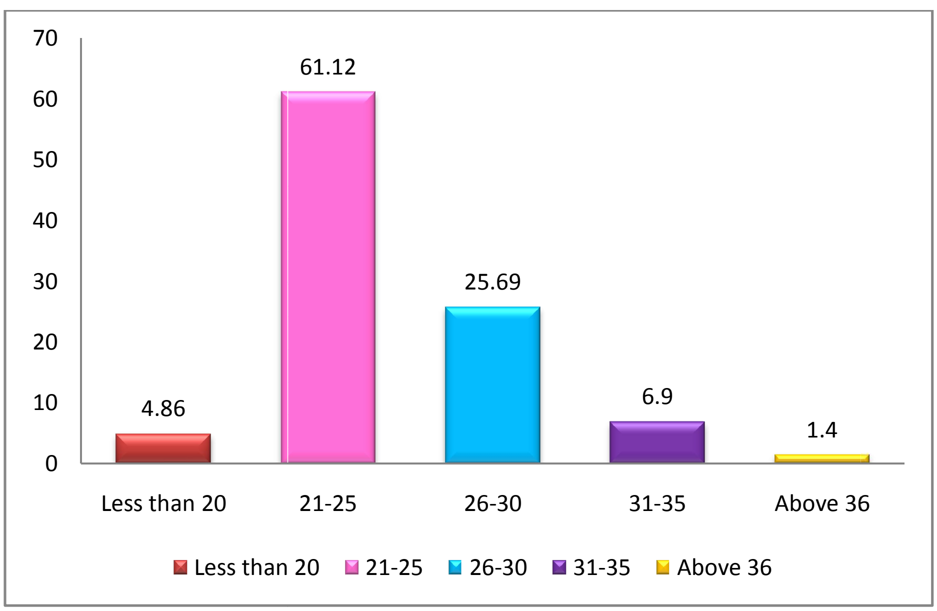
- Irregularity of astigmatism greater than 1.5 dioptres in the 3 mm diameter zone
- Irregularity of astigmatism greater than 2.5 dioptres in the 5 mm diameter zone
- Thinnest Pachymetry less than 470 microns
- Corneal thickness index greater than 1.16

Statistical analysis was performed by a standard biostatistician. Mean (SD) and Frequency (Percentage) were used for continuous and categorical variables respectively. Non-parametric Kruskal - Wallis test was used to assess the difference between the groups. Fisher's exact test or Chi-square test was used to assess the difference between the categorical variables. P-values less than 0.05 were considered statistically significant. All statistical analyses were done by the statistical software STATA 11.0.

OBSERVATION AND RESULTS

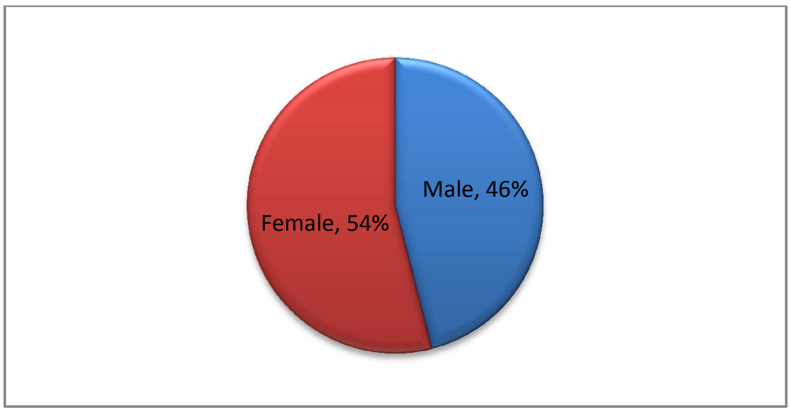
AGE GROUP OF THE PATIENTS

S.No	Age Group in years	No of Patients	Percentage
1	<20	7	4.8
2	21-25	88	61.1
3	26-30	37	25.6
4	31-35	10	6.9
5	>36	2	1.4
	Total	144	100



GENDER OF THE PATIENTS

S.No	Gender	No of patients	Percentage
1	Male	66	45.9
2	Female	78	54.1
	Total	144	100.00

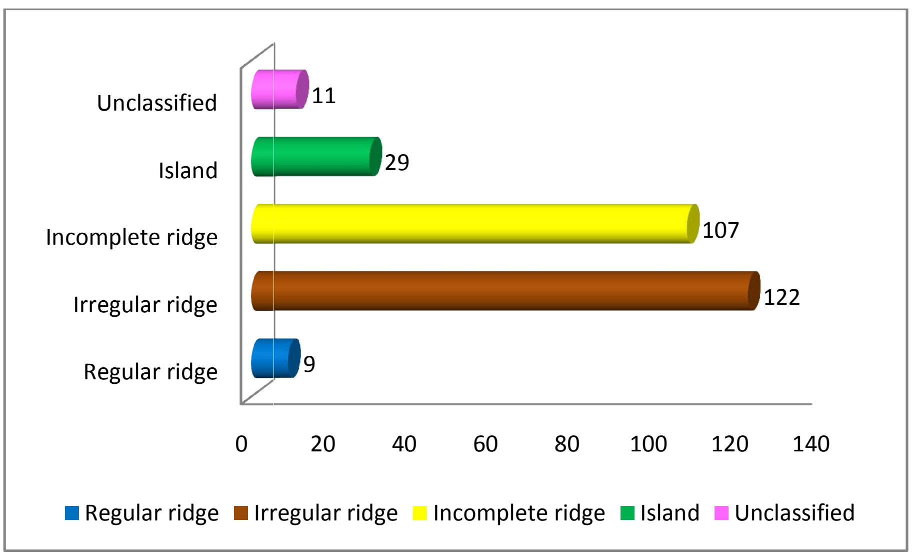


GENDER AND EYE CROSS TABULATION

S.No	Side of Eye	No of Eyes (%)	
		Male	**Female**
1	**Right**	65 (50.8 %)	75 (50%)
2	**Left**	63(49.2 %)	75 (50%)
	Total	128 (100%)	150 (100%)

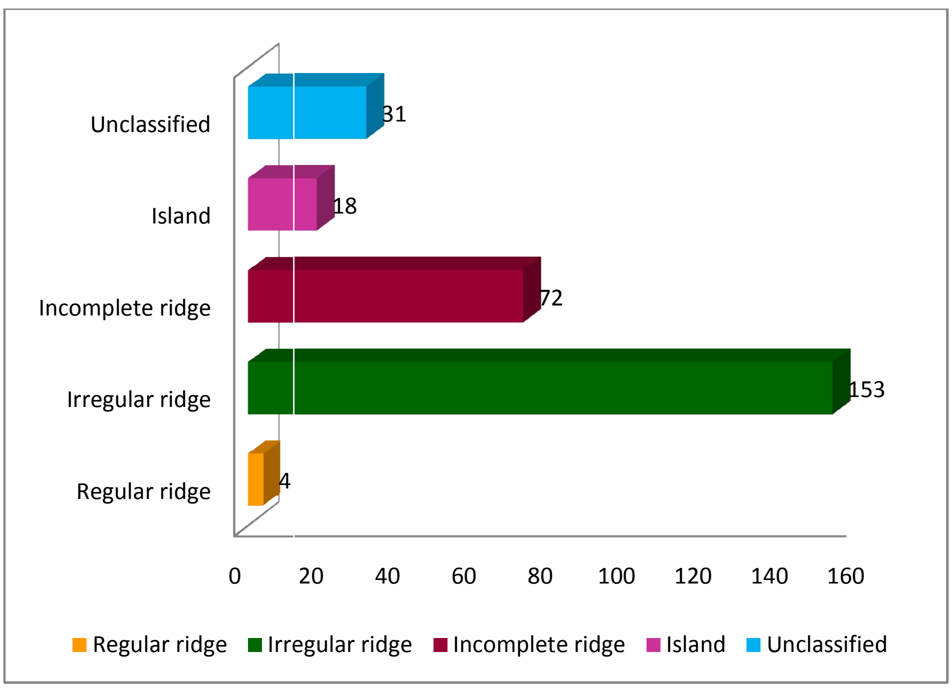
ANTERIOR ELEVATION PATTERN

Anterior Elevation Pattern	No of Eyes	%
Regular ridge	9	3
Irregular ridge	122	44
Incomplete ridge	107	38
Island	29	10
Unclassified	11	4
Total	278	100



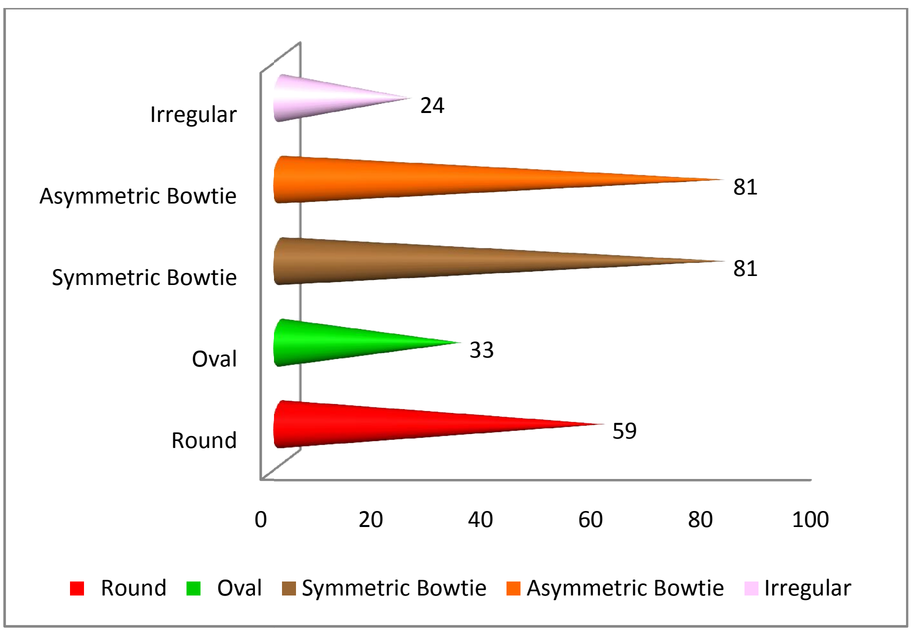
POSTERIOR ELEVATION PATTERN

Posterior Elevation Pattern	No of Eyes	%
Regular ridge	4	1
Irregular ridge	153	55
Incomplete ridge	72	26
Island	18	6
Unclassified	31	11
Total	278	100



AXIAL KERATOMETRY PATTERN

Axial Keratometry Pattern	No of Eyes	%
Round	59	21
Oval	33	12
Symmetric Bowtie	81	29
Asymmetric Bowtie	81	29
Irregular	24	9
Total	278	100



ANTERIOR AND POSTERIOR ELEVATION PATTERNS IN MALES & FEMALES

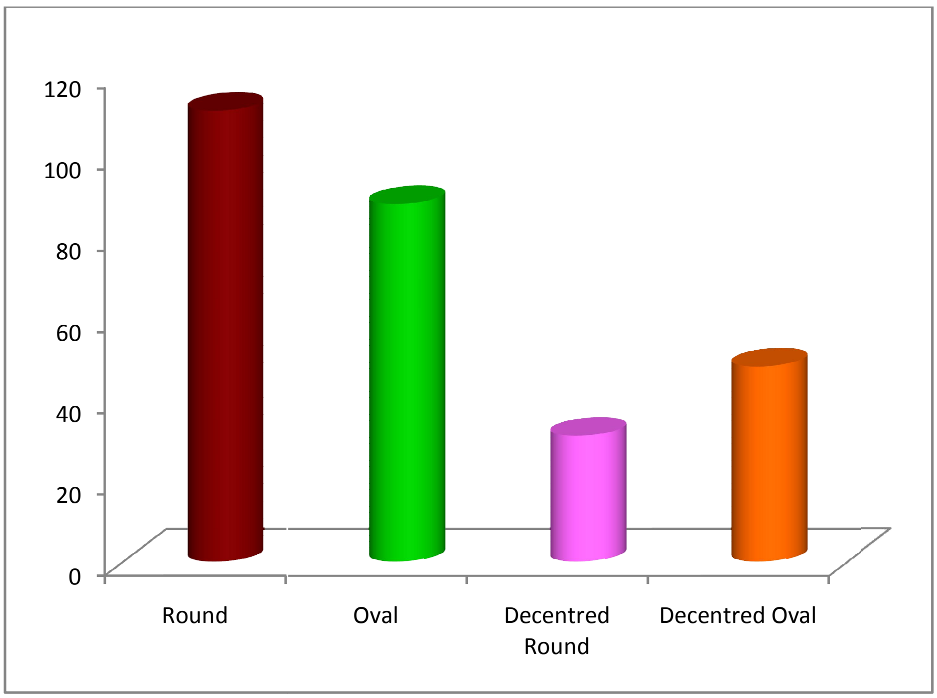
S.No	Elevation Pattern	(% of Eyes)			
		Anterior		Posterior	
		Male	Female	Male	Female
1	Regular Ridge	3.90	2.70	1.60	1.30
2	Irregular Ridge	44.50	43.30	54.70	55.30
3	Incomplete Ridge	39.90	37.30	24.20	27.30
4	Island	7.80	12.70	7.80	5.30
5	Unclassified	3.90	4.00	11.70	10.80

AXIAL KEROTOMETRY PATTERNS IN MALES & FEMALES

S.No	Axial Keratometry Pattern	(% of Eyes)	
		Male	Female
1	Round	21.90	20.70
2	Oval	12.50	11.30
3	Symmetric Bow Tie	25.00	32.70
4	Asymmetric Bow Tie	31.30	27.30
5	Irregular	9.40	8.00

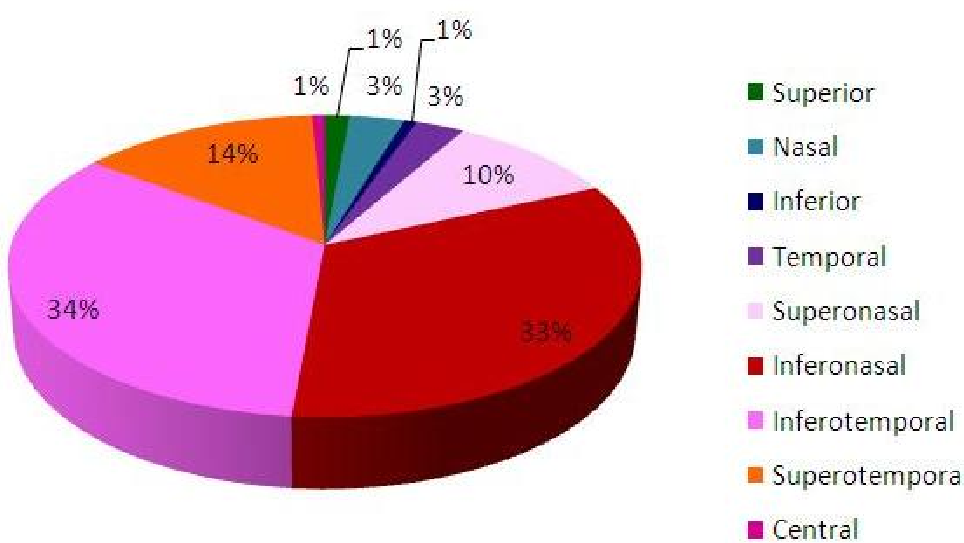
PACHYMETRY PATTERN

Pachymetry Pattern	No of Eyes	%
Round	111	40
Oval	88	32
Decentred Round	31	11
Decentred Oval	48	17
Total	278	100



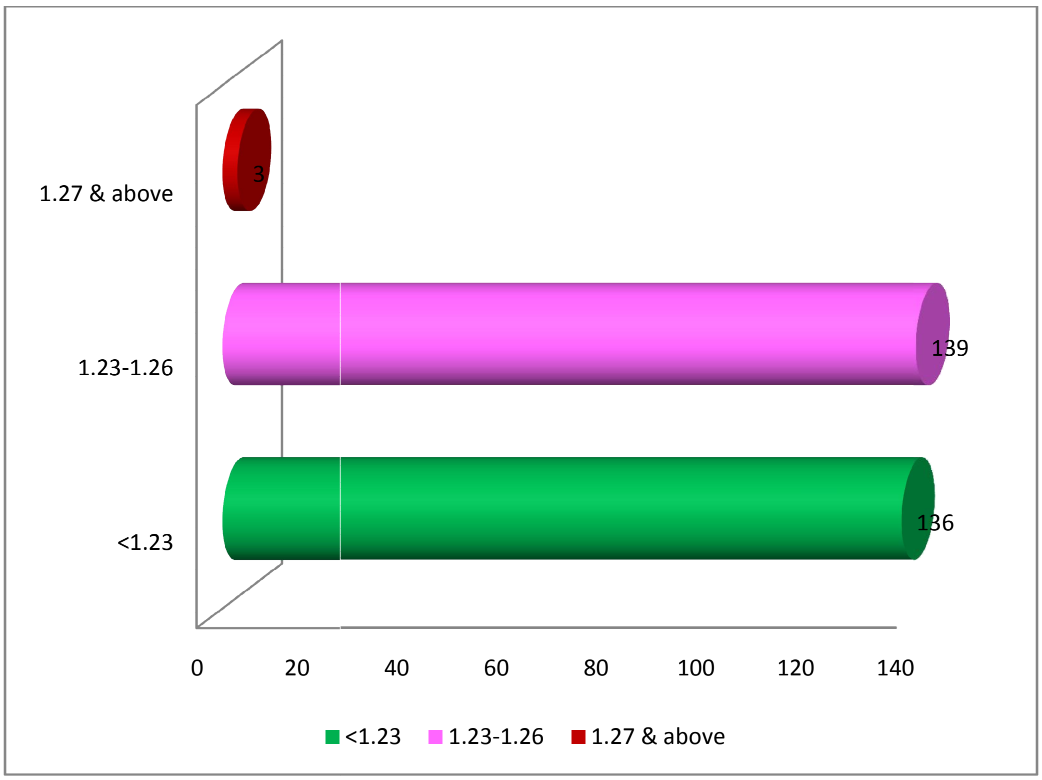
LOCATION OF THINNEST PACHYMETRY

Location	No of Eyes	%
Superior	4	1.4
Nasal	9	3.2
Inferior	2	0.7
Temporal	8	2.9
Superonasal	28	10.1
Inferonasal	92	33.1
Inferotemporal	94	33.8
Superotemporal	39	14
Central	2	0.7
Total	278	100



RATIO OF RADII OF ANTERIOR: POSTERIOR BFS

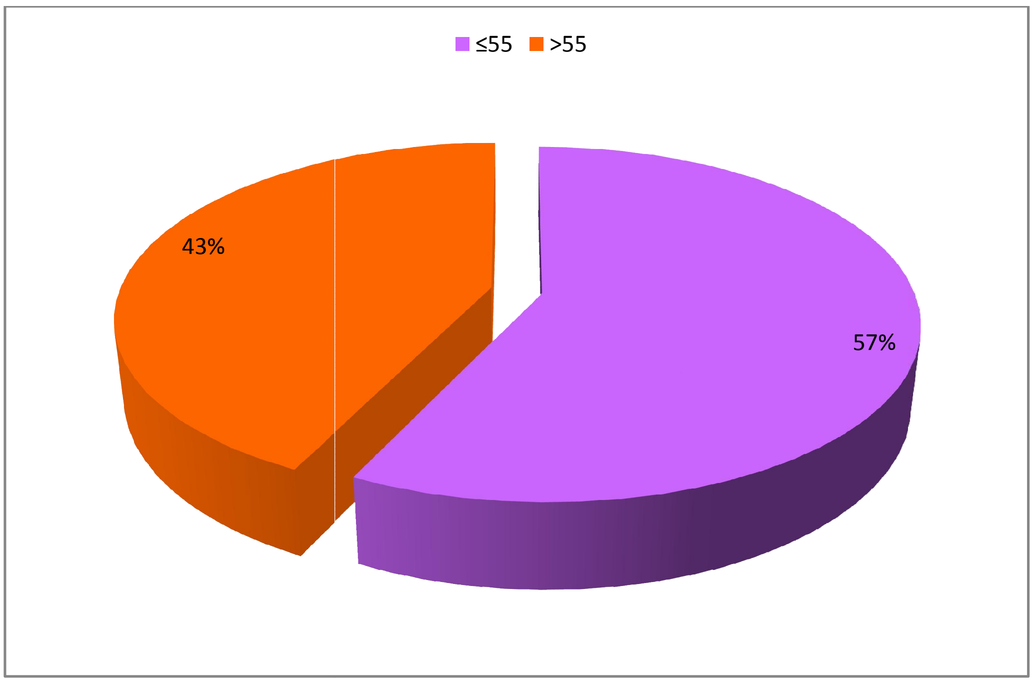
Ratio category	No of Eyes	%
<1.23	136	49
1.23-1.26	139	50
1.27 & above	3	1
Total	278	100



- 142 eyes (51%) had a ratio of radii of anterior BFS to posterior BFS of 1.23 or above. Of these, 139 eyes (50%) had the ratio within 1.23 to 1.26 whereas 3 eyes (1%) had a ratio more than 1.26.

POWER OF POSTERIOR BFS

Power of Posterior BFS	No of Eyes	%
≤55 D	159	57
>55 D	119	43
Total	278	100



Sim K Max

Sim K Max	**No of Eyes**	**%**
≤ 47.2 D	107	38
> 47.2 D	171	62
Total	278	100

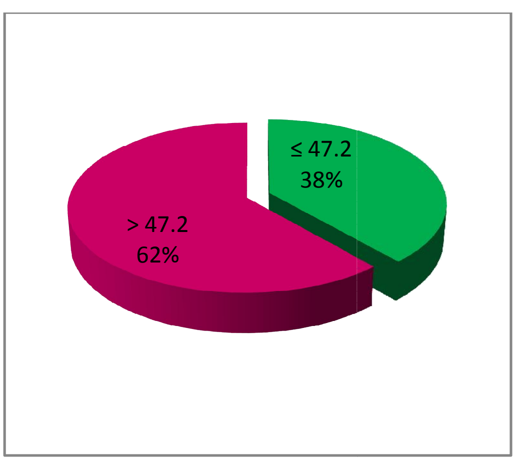
Mean (SD) of Sim K max is 47.2 D (2.0) and the range is 40.9 D- 61.3 D.

Sim K Min

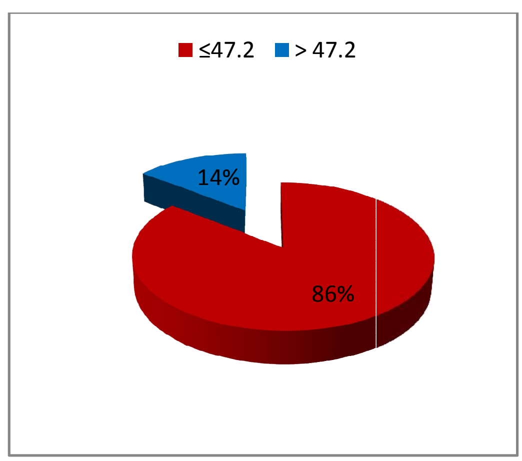
Sim K Min	**No of Eyes**	**%**
≤47.2 D	238	86
> 47.2 D	40	14
Total	278	100

Mean (SD) of Sim K Min is 45.8 D (1.7) and the range is 40.4 D -50.9 D.

Sim K Max



Sim K Min



3 MM IRREGULARITY

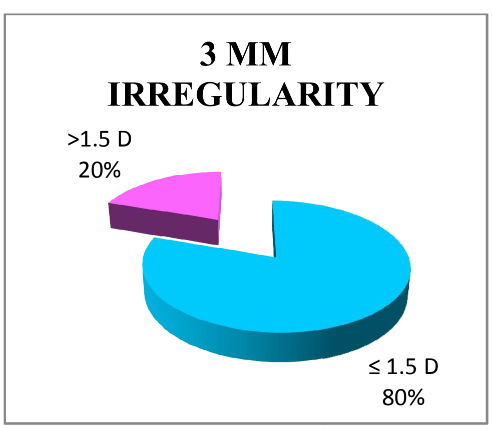
3 mm Irregularity	No of Eyes	%
≤ 1.5 D	223	80
>1.5 D	55	20
Total	278	100

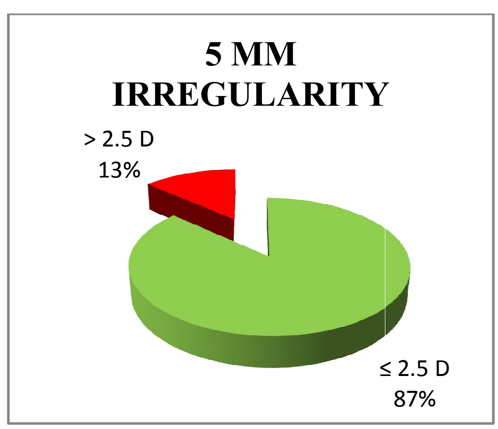
Mean (SD) of 3mm irregularity is 1.3 D (0.7) and the range is 0.4 D -6.2 D.

5 MM IRREGULARITY

5mm Irregularity	No of Eyes	%
≤ 2.5 D	241	87
> 2.5 D	37	13
Total	278	100

Mean (SD) of 5mm irregularity is 1.9 D (0.8) and the range is 0.8 D -7.3 D.

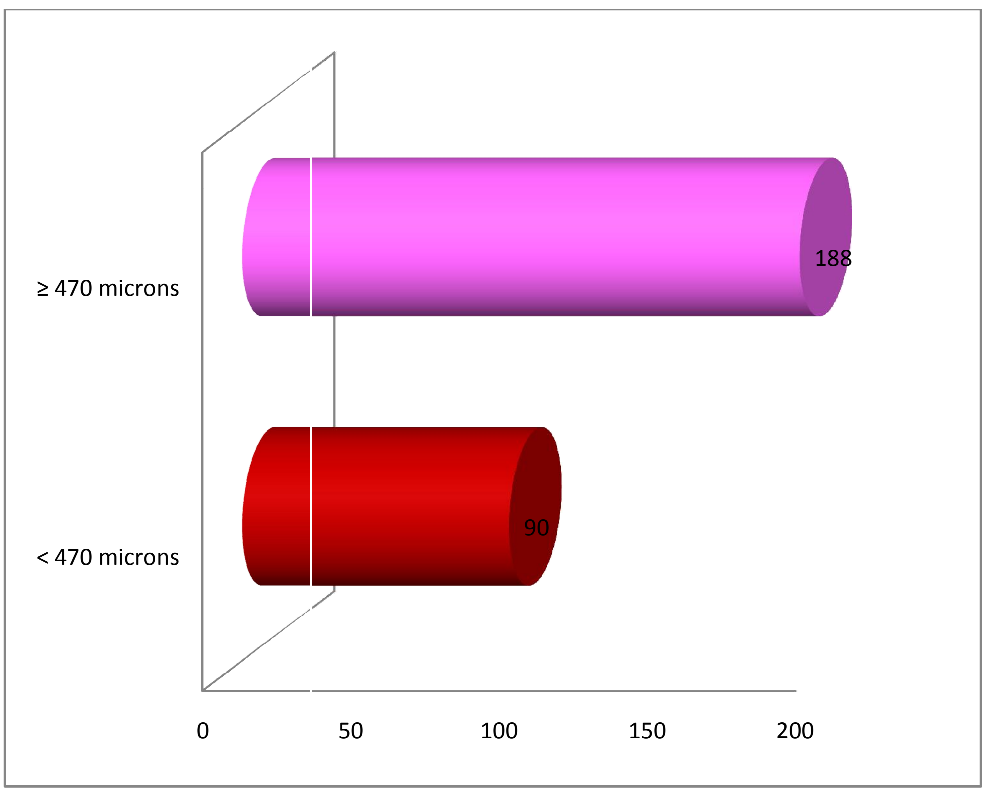




THINNEST PACHYMETRY

Thinnest Pachymetry	No of Eyes	%
< 470 microns	90	32
≥ 470 microns	188	68
Total	278	100

Mean (SD) of thinnest pachymetry is 500 microns (46.5) and the range is 386 microns – 623 microns.



MEAN (S.D) AND RANGE OF CORNEAL THICKNESS

Location	Mean Corneal Thickness (S.D) (microns)	Minimum Corneal Thickness (microns)	Maximum Corneal Thickness (microns)
Superior	605.7 (39.1)	520	737
Nasal	578.4 (44.5)	480	716
Inferior	580.4 (39.8)	483	701
Temporal	582.7 (45.9)	422	728
Central	508.7 (44.2)	401	625

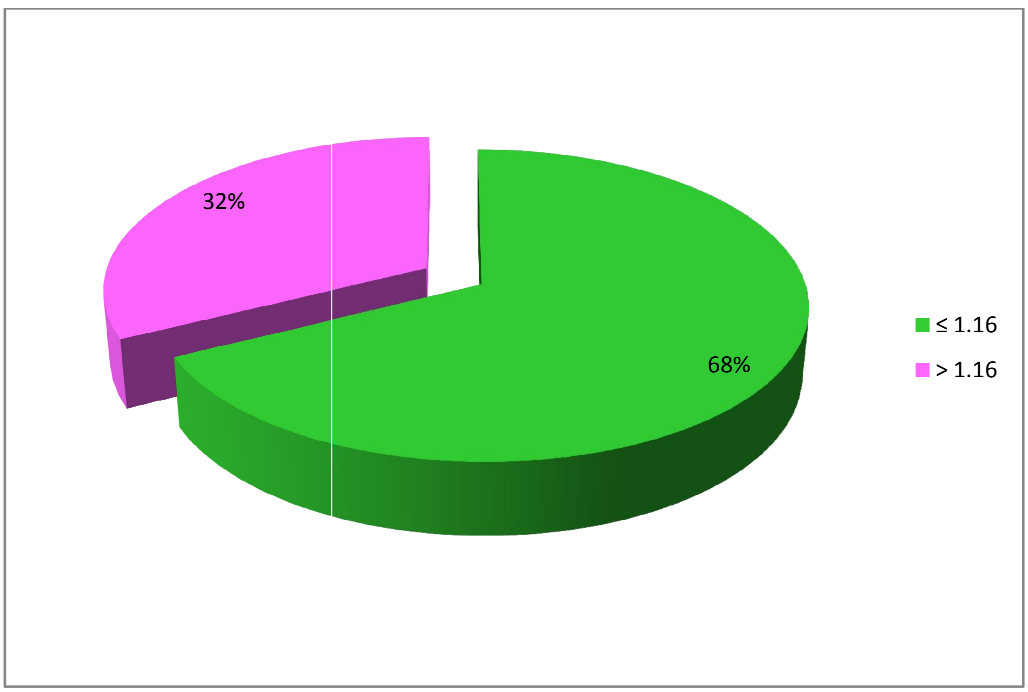
- The mean corneal thickness was highest in the superior zone (605.7 microns), followed by the temporal zone (582.7 microns), the inferior zone (580.4 microns) and the nasal zone (578.4 microns) with the lowest in the central zone (508.7 microns).

MEAN ASTIGMATISM

Mean (SD) of the Mean astigmatism is 1.4 D (1.1) and the range is from 0.1 D - 10.4 D.

CORNEAL THICKNESS INDEX (CTI)

CTI category	No of Eyes	%
≤ 1.16	188	67.6
> 1.16	90	32.4
Total	278	100



THINNEST PACHYMETRY & POWER OF POSTERIOR BFS

Thinnest Pachymetry	Power of Posterior BFS		Total	P-value
	≤ 55 D	>55 D		
<470 microns	74 82.2% 46.5%	16 17.8% 13.5%	90 100% 32.4%	<0.001
≥ 470 microns	85 45.2% 53.5%	103 54.8% 86.5%	188 100% 67.6%	
Total	159 57.2% 100%	119 42.8% 100%	278 100% 100%	

- Out of the 90 eyes with a thinnest pachymetry less than 470 microns, 16 eyes (17.8%) had a Power of Posterior BFS more than 55 D.
- Out of the 119 eyes with a Power of Posterior BFS more than 55 D, 16 eyes (13.5%) had a thinnest pachymetry less than 470 microns.

Sim K Max & POWER OF POSTERIOR BFS

Sim K Max	Power of Posterior BFS		Total	P-value
	≤ 55 D	**> 55 D**		
≤47.2 D	90 84.1% 56.6%	17 15.9% 14.3%	107 100% 38.5%	<0.001
> 47.2 D	69 40.4% 43.4%	102 59.7% 85.7%	171 100% 61.5%	
Total	159 57.2% 100%	119 42.8% 100%	278 100% 100%	

- Out of the 171 eyes with a Sim K Max more than 47.2 D, 102 eyes (59.7%) had a Power of Posterior BFS more than 55 D.
- Out of the 119 eyes with a Power of Posterior BFS more than 55 D, 102 eyes (85.7%) had a Sim K Max more than 47.2 D.

Sim K Max & PACHYMETRY

Sim K Max	Pachymetry		Total	P-value
	<470 microns	≥470 microns		
≤47.2 D	66 61.7% 73.3%	41 38.3% 21.8%	107 100% 38.5%	<0.001
>47.2 D	24 14% 26.7%	147 86% 78.1%	171 100% 61.5%	
Total	90 32.4% 100%	188 67.6% 100%	278 100% 100%	

- Out of the 90 eyes with a thinnest pachymetry less than 470 microns, 24 eyes (26.7%) had a Sim K Max more than 47.2 D.
- Out of the 171 eyes with a Sim K Max more than 47.2 D, 24 eyes (14%) had a thinnest pachymetry less than 470 microns.

POSTERIOR ELEVATION PATTERN VS ASTIGMATISM

Posterior Elevation Pattern	No of Eyes	Mean Astigmatism			P value*
		Mean (SD)	Median	Minimum to Maximum	
Regular ridge	4	1.90 D(1.21)	1.4 D	1.1 – 3.7 D	0.0001
Irregular ridge	153	1.65 D(1.15)	1.5 D	0.1 – 10.4 D	
Incomplete ridge	72	1.28 D(1.12)	0.9 D	0.1 – 6 D	
Island	18	0.72 D (0.45)	0.65D	0.2 – 1.8 D	
Unclassified	31	1.06 D (0.76)	0.9 D	0.1 – 3.6 D	
Total	278	1.43 D (1.11)	1.2 D	0.1 – 10.4 D	

*Kruskal-wallis test

- In the Posterior Elevation Patterns, the median of Mean Corneal Astigmatism was highest in the irregular ridge (1.5 D) followed by the regular ridge (1.4 D), incomplete ridge (0.9 D) and unclassified pattern (0.9 D) and the lowest was in the island pattern (0.6 D).

AXIAL KERATOMETRY PATTERN VS ASTIGMATISM

Axial Keratometry Pattern	No of Eyes	Mean Astigmatism			P value*
		Mean (SD)	Median	Minimum to Maximum	
Round	59	0.80 D (0.56)	0.7 D	0.1 – 2.8 D	**0.0001**
Oval	33	1.04 D (0.70)	0.9 D	0.1 – 3.9 D	
Symmetric Bowtie	81	1.91 D (0.87)	1.9 D	0.6 – 4.0 D	
Asymmetric Bowtie	81	1.71 D (1.48)	1.3 D	0.2 – 10.4 D	
Irregular	24	0.93 D (0.65)	0.9 D	0.1 – 2.4 D	
Total	278	1.43 D (1.11)	1.2 D	0.1 – 10.4 D	

*Kruskal-wallis test

- In the axial keratometry maps, the median of mean corneal astigmatism was highest in the symmetric bowtie pattern (1.9 D) followed by the asymmetric bowtie pattern (1.3 D), the oval pattern (0.9 D) and the irregular pattern (0.9 D) and the lowest was in the round pattern (0.7 D).

144 of 1518 (9.5%) refractive surgery candidates who were deemed clinically fit were consequently identified as poor candidates for Laser refractive surgery based on Orbscan II (Bausch & Lomb) corneal topography.

A total of 278 eyes of these 144 persons had abnormal topographic characteristics.

The age of the topographically rejected candidates was from 19 to 37 years with a mean average of 24.9 years (S.D 3.6).

The results showed that 61.1% of the people were in the age group from 21-25 years, followed by 25.6% in the 26-30 years age group. The 4.9% at the age of 20 years and below wanted to undergo laser refractive surgery for professional reasons.

The number of females was marginally more than males with a percentage of 54% to 46% respectively.

In the anterior elevation maps, the most common type observed was the irregular ridge pattern in both males (44.5%) and females (43.3%). The least observed type was the regular ridge pattern (2.7%) in females and both the regular ridge (3.9%) and unclassified patterns (3.9%) in males.

In the posterior elevation maps, similar results were seen with the irregular ridge pattern (54.7% in males and 55.3% in females) being the most common type and the regular ridge (1.6% in males and 1.7% in females) being the least common pattern.

In the axial keratometry maps both the symmetric and asymmetric bow tie patterns were equally common with a marginal predominance of asymmetric bow tie (31.3%) in males and symmetric bow tie (32.7%) in females. The irregular pattern (9.4% in males and 8% in females) was the least common axial keratometry pattern.

The most common pachymetry pattern was oval (52.3%) in males and round (44.7%) in females. The least common pachymetry was decentered round (8%) in females whereas in males both decentered round (14.8%) and decentered oval (14.8%) were least common.

The thinnest site of the cornea was predominantly located in the inferotemporal region in 94 eyes (33.8%), closely followed by the inferonasal region in 92 eyes (33.1%), superotemporal in 39 eyes (14%), superonasal in 28 eyes (10.1%), nasal in 9 eyes (3.2%), temporal in 8 eyes (2.9%), superior in 4 eyes (1.4%), inferior in 2 eyes (0.7%) and central in 2 eyes (0.7%).

119 eyes (43%) had a power of Posterior BFS greater than 55 dioptres.

171 eyes (62%) had a Simulated Maximum keratometry reading greater than 47.2 dioptres

55 eyes (20%) had an irregularity of astigmatism greater than 1.5 dioptres in the 3 mm diameter zone.

37 eyes (13%) had an irregularity of astigmatism greater than 2.5 dioptres in the 5 mm diameter zone.

90 eyes (32.4%) had a thinnest pachymetry less than 470 microns.

90 eyes (32.4%) had a Corneal Thickness Index greater than 1.16.

16 eyes (5.7%) had both thinnest pachymetry less than 470 microns and Power of Posterior BFS more than 55 D.

102 eyes (36.6%) had both Sim K Max more than 47.2 D and Power of Posterior BFS more than 55 D.

24 eyes (8.6%) had both Sim K Max more than 47.2 D and thinnest pachymetry less than 470 microns.

DISCUSSION

In the clinically normal myopic or hypermetropic population seeking Laser refractive surgery there are many subtle corneal shape abnormalities. Corneal topographic screening has proven to be the only effective way of detecting these changes. We conducted this study to analyse the characteristics of such corneas.

David Varssanoet al[3] reported that 27 of 200 eyes (13.5%) were rejected for refractive surgery based on corneal topography alone. Nesburnet al[16]reported 6 of 91 patients (6.6%) as having abnormal corneas when screening with videokeratography for refractive surgery. Renato Ambrosioet al[18] gave an incidence of 1.3% (18 of 1392 refractive surgery candidates) as having abnormal corneal topographies. In our study a different incidence was seen with 144 of 1518 clinically normal candidates (9.5%) rejected based on corneal topography alone.

The corneal topographic characteristics of our study candidates were also markedly different from that of the normal population for various patterns and indices.

In the study by Zuguo Liu et al[23] of normal eyes, the most common anterior elevation pattern was the island (71.7%) and the least common was the unclassified (2.17%). This was very much different in our study with the most common pattern being irregular ridge (44%) and the least common pattern being regular ridge (3%).

Similarly in the posterior elevation patterns where the island (32.6%) was the most common in normal eyes, ours showed that the irregular ridge (55%) was the most common. Moreover in the normal eyes the irregular ridge (13%) was the least observed pattern with no eyes exhibiting an unclassified pattern. But our least observed posterior elevation pattern was the regular ridge (1%).

Many studies have shown that the different types of axial keratometry patterns[23, 25, 43] occur variably irrespective of normal or abnormal corneas. In Kanpolat A et al[43] the asymmetric bowtie (33%) was the most common with the oval pattern (11%) being the least observed. In Zuguo Liu et al[23] the symmetric bowtie (39.1%) was the most frequently seen and the irregular type (4.5%) was the least seen. In our candidates, both the symmetric and asymmetric bowtie patterns were equally frequent (29%) with the irregular type (9%) being the least frequent.

The pachymetric pattern derived by Zuguo et al[23] showed that the oval pattern (47.8%) was predominant and the decentered round (2.1%) was rarest. However in our study the round pattern (40%) was predominant with the decentered round (11%) being the least seen pattern.

In the Zuguo Liu et al[23] and Bina John et al[22] studies, the location of the thinnest point of the cornea was most commonly observed in the inferotemporal region (69.5%) and (77.8%) respectively. The least observed location was the superonasal (2.1%) and inferonasal (2.8%) regions respectively. In our study also the most common location was in the inferotemporal region (33.8%) but was closely followed by the inferonasal region (33.1%). In contrast the least common locations were in the inferior region (0.7%) and central region (0.7%).

The correlation between steep corneas (Sim K Max more than 47.2 D), thin corneas (thinnest pachymetry less than 470 microns) and Power of Posterior BFS more than 55 D was statisitically significant ($P<0.001$) in our study.

There was a statistically significant difference ($P = 0.0001$) in the mean corneal astigmatism among the posterior elevation patterns similar to the study by Naufalet al[26]. Further, the difference in mean corneal astigmatism was statistically significant among the axial keratometry patterns also.

CONCLUSION

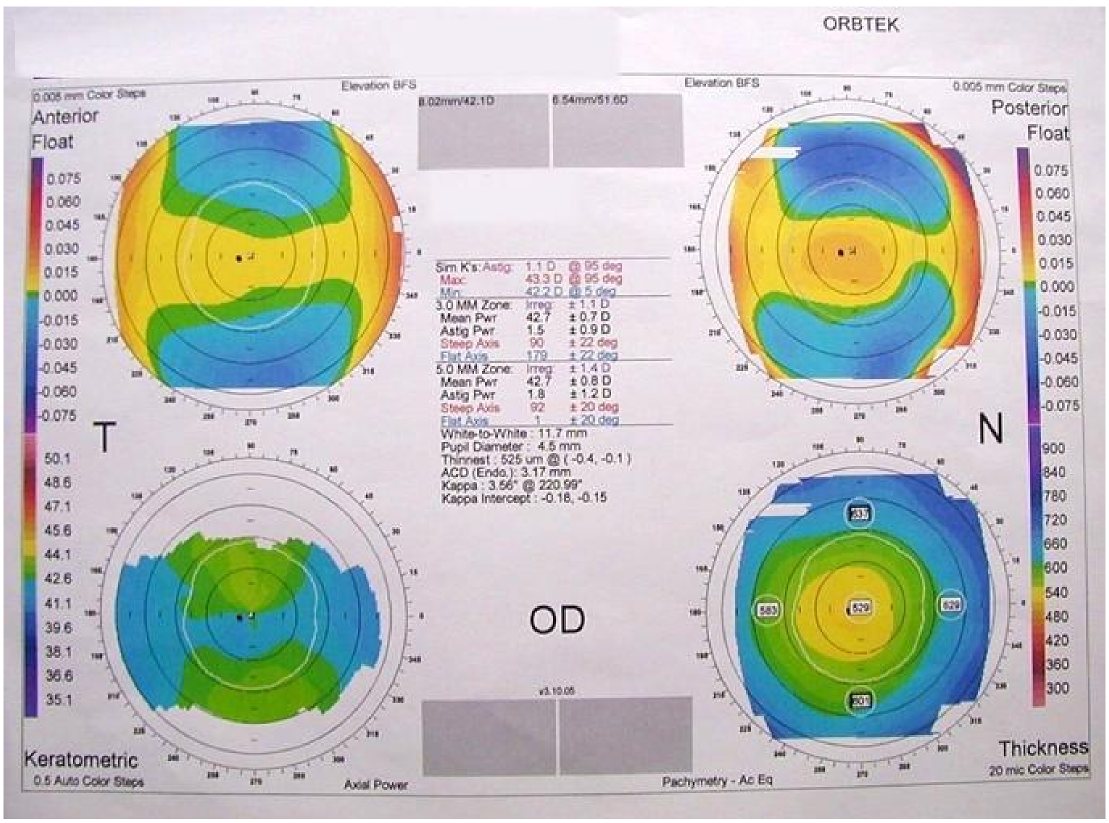
An average refractive surgery practice witnesses an increase in the incidence of corneal topographic abnormalities when compared to that in the general population. This is because many patients having abnormal corneal topography are not satisfied with the use of glasses or contact lens due to poor quality of images formed. Hence these patients self -select themselves more often and opt for Laser refractive correction[35].

Persons with ectasia have been found to have preoperative corneal topographies with frank or probable keratoconus, thin pachymetry and other ectatic disorders. As the shape of the cornea appears to conform more to that of keratoconus there is an increased risk of keratectasia. Many studies have been done to establish a criterion for distinguishing normal corneas from abnormal corneas[38, 39, 41]. But very few have given the associations between various topographic characteristics of the abnormal corneas in the same group at a single point of time.

Our study provides new and detailed information of the corneal topographic patterns and quantitative indices in eyes which are sub-clinically ectatic or at risk for ectasia. Also, this study, having been conducted in a large and diverse tertiary eye care setup, could prove to be a reference for correlation in a sample of the South Indian population.

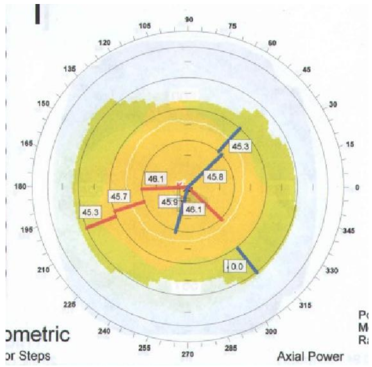
ORBSCAN II TOPOGRAPHER (BAUSCH & LOMB)

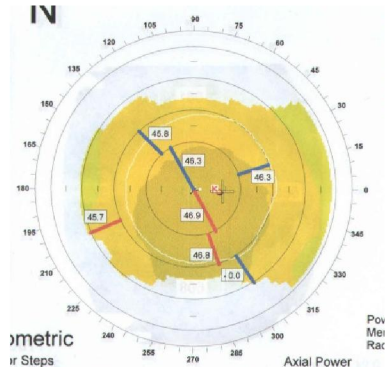
EXAMPLE OF A NORMAL ORBSCAN



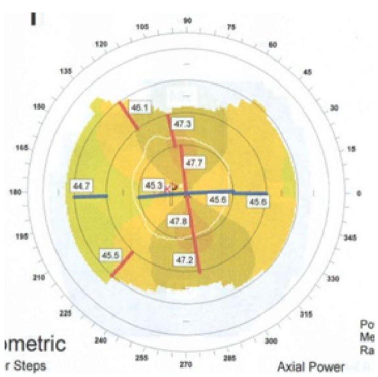
TYPES OF AXIAL KERATOMETRY PATTERNS

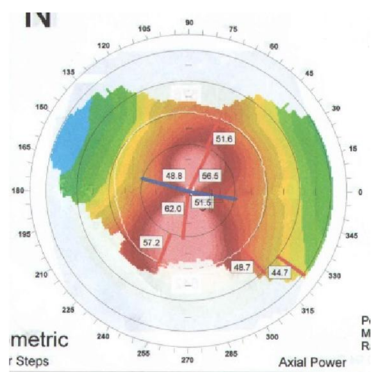
Round Pattern **Oval Pattern**



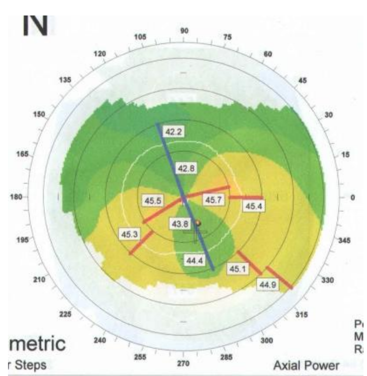


Symmetric bowtie Pattern **Asymmetric bowtie Pattern**



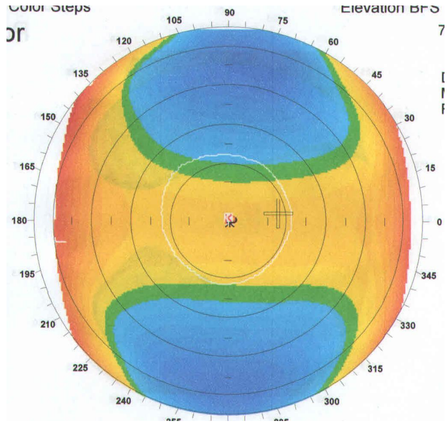


Irregular Pattern

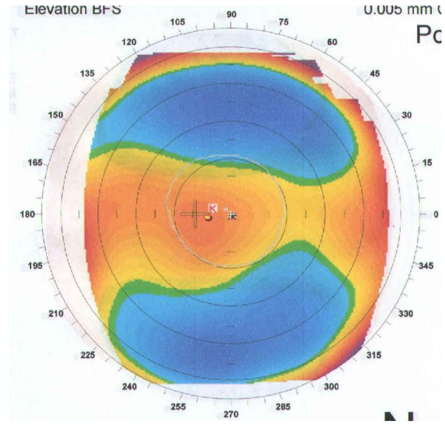


TYPES OF ELEVATION PATTERNS

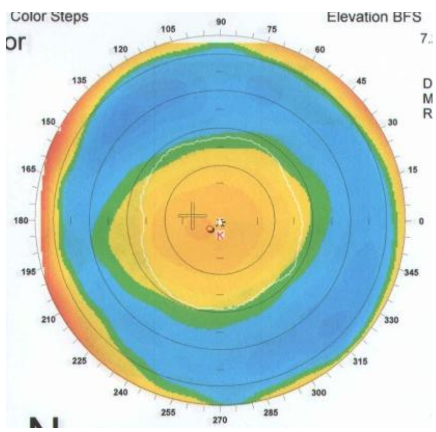
Regular Ridge Pattern



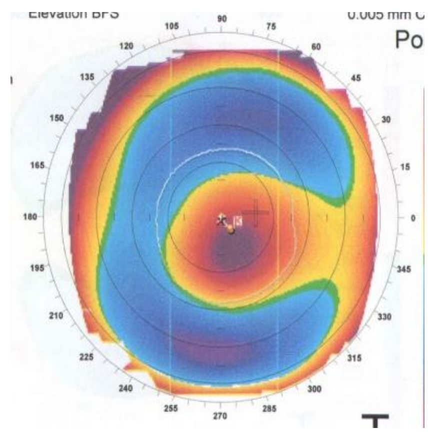
Irregular Ridge Pattern



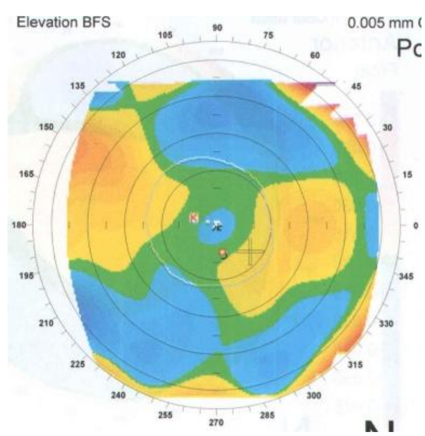
Island Pattern



Incomplete Ridge Pattern

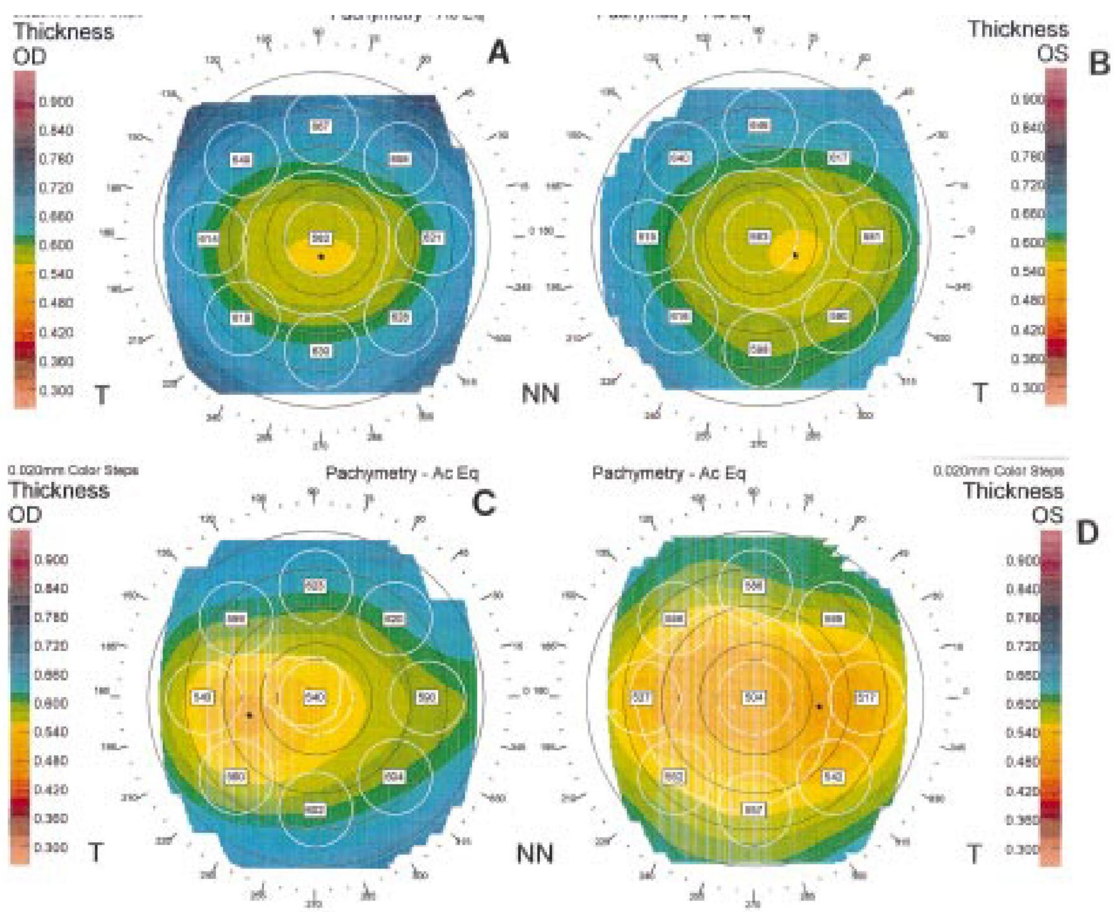


Unclassified Pattern

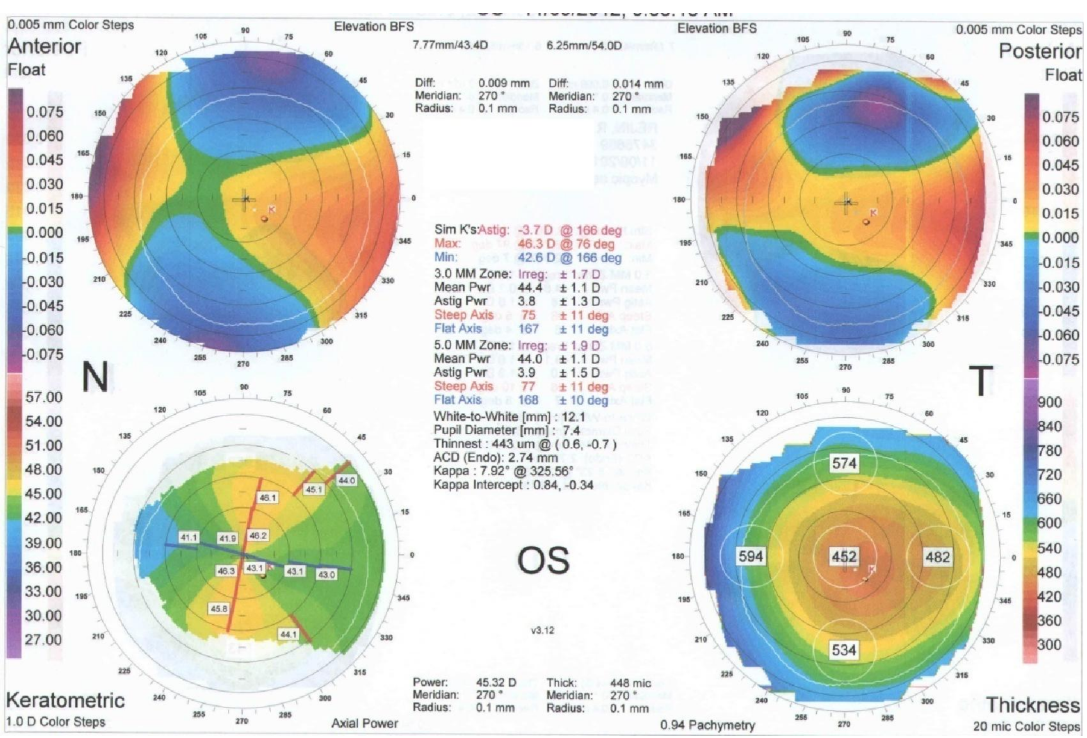


TYPES OF PACHYMETRIC PATTERNS (LIU ET AL)

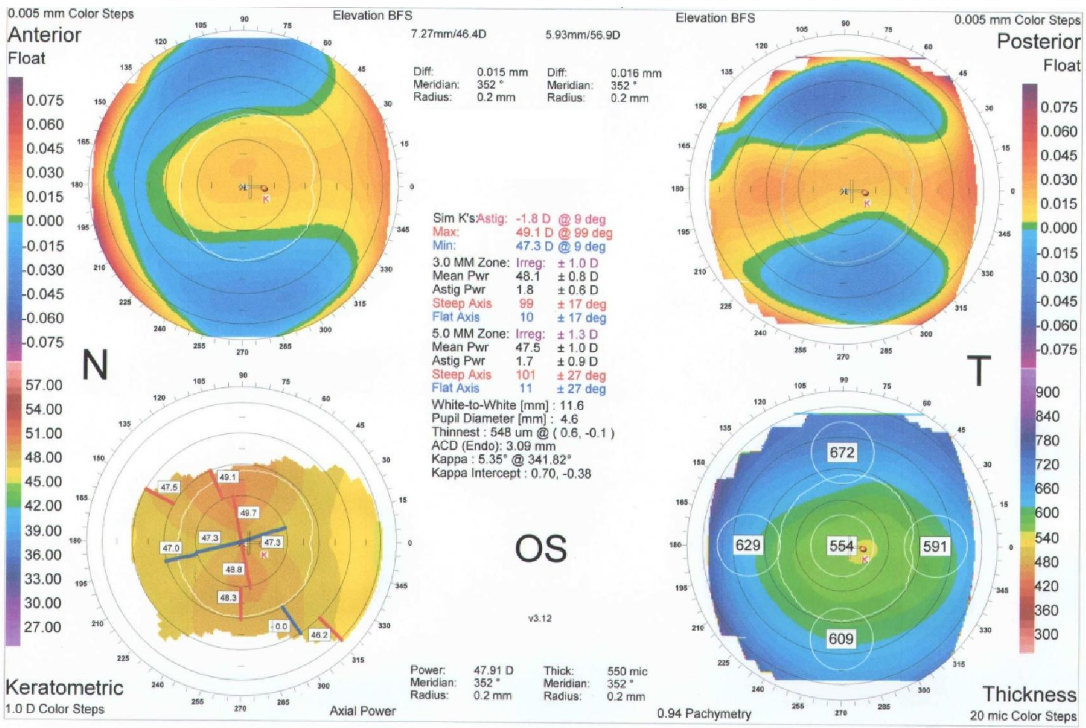
A).Oval B).Round C).Decentred Round D).Decentred Oval



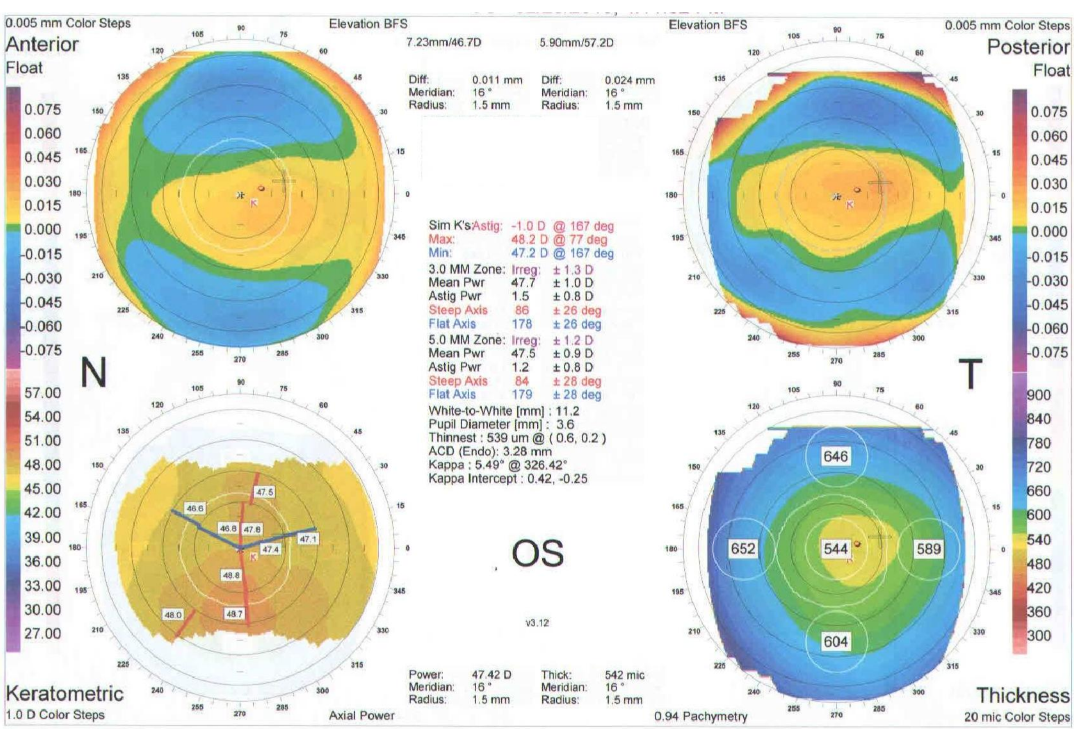
Orbscan Showing Thin Cornea



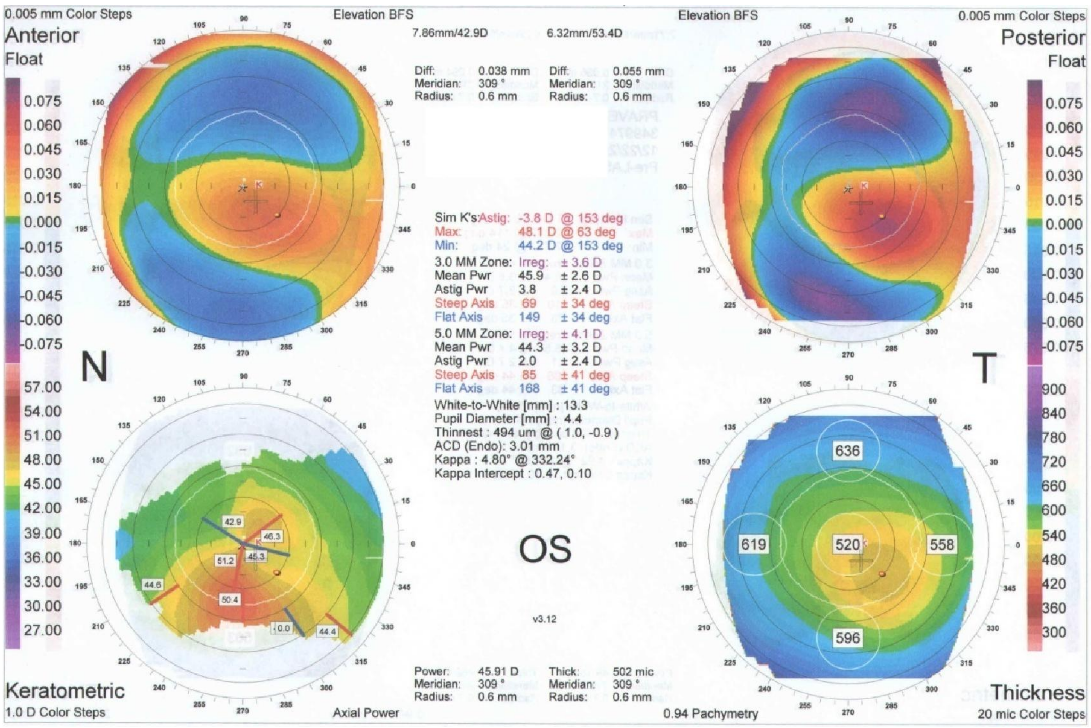
Orbscan Showing Steep Cornea



Orbscan of Forme Fruste Keratoconus (FFKC)



Orbscan of Keratoconus



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Corneal Topographic Characteristics of Persons Seeking Laser Refractive Surgery

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Proforma

MR No: _______　　　　**Case No:** [ ]

Name:_________

Age(years): [ ]

Eye: [ ]

1. Right
2. Left

Sex: [ ]

1. Male
2. Female

Diagnosis: _________

TOPOGRAPHIC CHARACTERISTICS

Anterior elevation pattern:

1. Regular ridge
2. Irregular ridge
3. Incomplete ridge
4. Island
5. Unclassified

Posterior Elevation pattern:

1. Regular ridge
2. Irregular ridge
3. Incomplete ridge
4. Island
5. Unclassified

Axial Keratometry pattern:

1. Round
2. Oval
3. Symmetric Bowtie
4. Asymmetric Bowtie
5. Irregular

Pachymetry pattern: ☐

1. Round
2. Oval
3. Decentered Round
4. Decentered Oval

Location of Thinnest Pachymetry: ☐

1. Superior
2. Nasal
3. Inferior
4. Temporal
5. Superonasal
6. Inferonasal
7. Inferotemporal
8. Superotemporal
9. Central

TOPOGRAPHIC INDICES

1. **Radius of Anterior BFS (mm): ______**

2. **Radius of Posterior BFS (mm): ______**

3. **Ratio of radii of anterior BFS to Posterior BFS: ______**

4. **Power of Anterior BFS (dioptres): ______**

5. **Power of Posterior BFS (dioptres): ______**

6. **MeanAstigmatism (dioptres): ______**

7. **Sim K Max (dioptres): ______**

8. **Sim K Min (dioptres): ______**

9. **Irregularity of Astigmatism in 3mm diameter zone (dioptres): ______**

10. Irregularity of Astigmatism in 5mm diameter zone (dioptres): ______

11. Thinnest Pachymetry (microns): ______

12. Corneal Thickness (microns):

a. Superior:______

b. Nasal:______

c. Inferior:______

d. Temporal:______

e. Mean of superior, nasal, inferior and temporal:______

f. Central:______

13. Corneal Thickness Index (CTI): ______

ABBREVIATIONS

LASIK	-	Laser Assisted In Situ Keratomileusis
PRK	-	Photorefractive Keratectomy
BFS	-	Floating Best Fit Sphere
D	-	Dioptres
K	-	Keratometry
mm	-	millimeters
Sim K Max	-	Simulated Maximum Keratometry
Sim K Min	-	Simulated Minimum Keratometry
CTI	-	Corneal Thickness Index

INFORMED CONSENT

I , , hereby give my consent to be a part of the study entitled "**CORNEAL TOPOGRAPHIC CHARACTERISTICS OF PERSONS SEEKING LASER REFRACTIVE SURGERY**"as one of the subjects. I have been fully explained to my satisfaction about the procedure in my own language.Iam giving this consent of my free will.

Signature/ left thumb impression.

Date

MASTER CHART

MR No	Name	Age	Sex	Eye	Anterior Elevation Pattern	Posterior Elevation Pattern	Axial Keratometry Pattern	Pachymetry Pattern	Radius of Anterior BFS	Radius of Posterior BFS	Ratio of radii of Anterior:Posterior BFS	Power of Anterior BFS	Power of Posterior BFS	Mean astigmatism	Degrees	Sim K Max	Sim K Min	3mm irregularity	5mm irregularity	Thinnest Pachymetry	Location of thinnest Pachymetry	Corneal thickness						Corneal thickness index
																						Superior	Nasal	Inferior	Temporal	Mean	Central	
3479118	Abdul rahoof k	22	1	1	2	3	4	1	7.46	6.14	1.21	45.2	54.9	-5.6	19	52.1	46.6	5.3	5.3	388	7	554	558	533	518	540.75	408	1.33
3479118	Abdul rahoof k	22	1	2	2	3	4	1	7.55	6.13	1.23	44.7	55	-3.7	163	50.5	46.8	4.7	4.7	393	6	540	505	532	548	531.25	404	1.31
3484321	Abdul rahman t	28	1	2	2	2	3	1	7.43	6.03	1.23	45.4	56	-1.6	14	48.3	46.7	1.1	1.7	550	6	617	620	613	627	619.25	553	1.12
3484321	Abdul rahman t	28	1	1	2	2	4	4	7.49	6.15	1.22	45	54.8	-1.6	3	47.6	46.1	1	1.5	547	6	642	622	591	613	617	557	1.11
3496659	Abhiraj a	23	1	2	3	2	3	3	7.54	6.03	1.25	44.7	55.9	-3.7	175	48.3	44.6	1.3	2.1	541	5	677	582	615	690	641	551	1.16
3496659	Abiraj a	23	1	1	3	2	3	3	7.54	6.09	1.24	44.7	55.5	-1	161	46.7	45.7	0.8	1.5	532	8	650	632	633	602	629.25	544	1.16
3353688	Adarsh a	22	1	2	3	2	3	3	8.45	6.9	1.22	40	48.9	-3	168	47.9	42.9	1.2	2.1	526	6	597	538	607	626	592	542	1.09
3353688	Adarsh a	22	1	1	1	2	3	1	8.24	6.65	1.24	41	50.7	-4	17	47.3	43.3	1.3	1.5	532	6	610	588	605	583	596.5	535	1.11
3421697	Anuvidhya sankari p	21	2	1	3	2	1	3	7.69	6.36	1.21	43.9	53.1	-0.9	14	47.3	46.4	0.6	1	492	7	613	606	558	559	584	503	1.16
3421697	Anuvidhya sankari p	21	2	2	4	3	1	1	7.64	6.29	1.21	44.2	53.7	-0.6	160	46.4	45.8	0.9	1.6	502	7	599	578	585	574	584	506	1.15
3552703	Archana s	33	2	1	3	2	3	1	7.69	6.21	1.24	43.9	54.3	-1.6	171	47.2	45.6	0.9	1.6	524	8	604	632	609	565	602.5	531	1.13
3552703	Archana s	33	2	2	3	2	3	1	7.6	6.06	1.25	44.4	55.7	-1.9	179	47.6	45.7	0.9	1.5	519	6	621	586	601	610	604.5	525	1.15
3200781	Aruna t	21	2	2	2	2	3	4	7.36	5.97	1.23	45.9	56.6	-1.6	180	48.1	46.5	0.9	1.3	548	6	661	597	609	639	626.5	559	1.12
3200781	Aruna t	21	2	1	1	2	3	2	7.37	5.99	1.23	45.8	56.4	-1.3	161	47.1	45.8	1	1.3	546	7	654	609	607	598	617	550	1.12
3576686	Arunthathi s	28	2	1	2	1	2	3	7.39	6.09	1.21	45.6	55.4	-1.1	176	46.7	45.7	1.9	1.8	533	7	664	650	627	615	639	554	1.15
2357390	Ashokvarman a	24	1	1	3	2	1	1	7.66	6.16	1.24	44.1	54.8	-0.7	176	45.8	45.1	0.9	1.6	469	7	588	560	553	559	565	475	1.19
2357390	Ashokvarman a	24	1	2	2	5	2	1	7.67	6.19	1.24	44	54.5	-0.9	163	45.6	44.7	0.8	1.2	473	8	594	550	549	566	564.75	480	1.18
3344783	Aswini a	22	2	2	2	1	2	1	7.84	6.53	1.20	43.1	51.7	-1.5	21	47.6	46.1	0.6	0.8	506	8	603	565	599	573	585	511	1.14
3344783	Aswini a	22	2	1	2	2	3	2	7.85	6.55	1.20	43	51.6	-2.3	179	47.5	45.2	0.4	0.9	505	7	609	577	588	568	585.5	512	1.14
3580593	Bala abirami r	27	2	2	2	3	1	1	7.62	6.26	1.22	44.3	53.9	-0.9	3	47.9	47	0.8	1.2	511	2	606	586	564	568	581	515	1.13
3580593	Bala abirami r	27	2	1	2	3	1	1	7.61	6.25	1.22	44.4	54	-0.3	5	47.3	46.9	0.4	0.9	508	8	612	575	585	579	587.75	513	1.15
3579085	Balasubramanian n	23	1	2	4	4	1	1	8.1	6.77	1.20	41.7	49.9	-0.6	9	44.3	43.8	1	1.6	433	2	536	503	534	533	526.5	438	1.20
3579085	Balasubramanian n	23	1	1	4	2	1	1	8.3	6.69	1.24	40.7	50.4	-0.4	14	43.7	43.3	1.4	2	423	7	546	490	538	527	525.25	429	1.22
3417170	Balachandar a	25	1	2	3	3	5	2	7.6	6.38	1.19	44.4	52.9	-0.5	12	47.3	46.8	0.9	1.9	495	6	565	552	555	569	560.25	502	1.12
3586242	Balkees banu j	25	2	2	2	4	2	1	7.18	5.9	1.22	47	57.2	-0.7	7	48.5	47.8	0.9	1.1	585	2	679	662	669	667	669.25	591	1.13
3586242	Balkees banu j	25	2	1	2	4	1	1	7.23	5.85	1.24	46.7	57.7	-0.4	157	48.3	47.8	0.7	1.2	583	7	654	672	673	648	661.75	591	1.12
3523313	Banupriya r	26	2	2	3	4	4	1	7.32	5.96	1.23	46.1	56.6	-0.6	7	48.7	48.1	0.8	1.4	524	6	613	565	584	609	592.75	529	1.12
3523313	Banupriya r	26	2	1	4	5	5	1	7.33	5.95	1.23	46.1	56.7	-0.4	145	48.4	48.1	1.1	1.3	517	8	612	595	593	567	591.75	532	1.11
3516128	Bhargavi t	25	2	1	5	5	5	2	7.95	6.29	1.26	42.5	53.7	-1	34	47.4	46.4	0.8	1.5	484	7	606	597	577	552	583	493	1.18

3516128	Bhargavi t	25	2	2	5	4	5	3	7.95	6.4	1.24	42.4	53.8	-0.2	89	47.1	46.9	0.9	1.4	487	6	640	565	538	606	587.25	502	1.17
3231293	Deepa m	27	2	2	2	2	3	1	7.25	5.92	1.22	46.5	57	-1.6	32	48.3	46.7	0.9	1.2	610	5	689	668	681	728	691.5	618	1.12
3231293	Deepa m	27	2	1	1	2	4	1	7.21	5.93	1.22	46.8	57	-1.7	170	48.7	46.9	0.8	1.3	622	8	702	709	682	674	691.75	625	1.11
1665812	Dhanalakshmi c	21	2	2	3	5	4	3	7.44	6.11	1.22	45.4	55.3	-0.6	35	47.6	47.1	1.3	1.5	541	5	607	590	609	621	606.75	552	1.10
3527859	Dheepika s	24	2	1	4	2	4	1	7.52	6.15	1.22	44.9	54.9	-1	25	47.9	46.9	1.3	2.2	500	7	612	574	561	559	576.5	506	1.14
3527859	Dheepika s	24	2	2	3	2	4	2	7.61	6.11	1.25	44.3	55.3	-1.1	159	48.1	47	1.4	2.6	506	6	631	537	552	600	580	511	1.14
3538145	Dhulasybrindha m	21	2	1	3	3	1	4	7.61	6.33	1.20	44.3	53.4	-0.5	13	45.8	45.3	0.7	1	465	5	537	566	568	523	548.5	475	1.15
3341963	Durga p	25	2	2	3	2	1	2	7.71	6.25	1.23	43.8	54	-0.6	4	47.6	47	0.8	1.2	472	6	594	541	564	590	572.25	479	1.19
3341963	Durga p	25	2	1	3	2	1	1	7.81	6.34	1.23	43.2	53.2	-0.8	173	47.5	46.7	0.9	1.5	477	7	600	577	558	537	568	483	1.18
3487419	Eswari p	23	2	2	3	5	3	2	7.39	6.03	1.23	45.7	56	-1.4	173	48.2	46.8	1.5	1.9	476	7	585	522	543	578	557	481	1.16
3487419	Eswari p	23	2	1	3	2	3	4	7.44	6.09	1.22	45.3	55.4	-0.6	170	47.8	47.2	0.8	1.5	477	7	566	556	564	522	552	485	1.14
3511387	Fathimarefana j	21	2	2	4	2	1	1	7.65	6.25	1.22	44.1	54	-0.3	102	48	47.7	0.5	1.2	477	6	563	521	555	583	555.5	482	1.15
3511387	Fathimarefana j	21	2	1	3	2	1	4	7.69	6.26	1.23	43.9	53.9	-0.3	85	45.7	45.4	0.7	1.2	467	7	571	581	554	520	556.5	483	1.15
3572453	Gladima nisia t	33	2	2	3	2	4	1	7.39	6.08	1.22	45.6	55.5	-0.9	156	47.9	47	0.8	1.6	523	4	602	575	576	592	586.25	526	1.11
3572453	Gladima nisia t	33	2	1	2	2	4	1	7.36	5.99	1.23	45.9	56.3	-1.3	19	48.2	46.9	1.2	1.6	508	7	598	597	577	567	584.75	517	1.13
3556322	Gopinath m	29	1	2	2	3	5	2	7.48	6.04	1.24	45.1	55.9	-2.3	76	49	46.7	1.6	2.8	443	7	567	565	531	540	550.75	458	1.20
3556322	Gopinath m	29	1	1	2	3	5	2	7.41	5.94	1.25	45.6	56.8	-1.5	114	48.1	46.6	1	1.4	570	6	665	646	668	650	657.25	572	1.15
3386682	Gurunathan p	22	1	1	2	4	4	4	7.78	6.46	1.20	43.4	52.2	-0.4	163	44.6	44.2	2	2.3	466	7	555	535	517	539	536.5	478	1.12
3386682	Gurunathan p	22	1	2	3	3	3	3	7.74	6.42	1.21	43.6	52.6	-0.7	176	44.8	44.1	1.9	2	453	5	541	507	531	540	529.75	475	1.12
3288874	Hameetha sithika h	28	2	1	2	3	3	1	7.49	6.29	1.19	45	53.6	-1	143	47.6	45.6	0.9	1.4	512	6	613	565	572	583	583.25	517	1.13
3288874	Hameetha sithika h	28	2	2	1	2	3	2	7.54	6.27	1.20	44.8	53.8	-2.5	10	47.7	45.2	1	1.4	526	5	621	566	599	613	599.75	531	1.13
3508680	Harikeerthana k	24	2	1	2	2	3	1	7.16	5.84	1.23	47.1	57.8	-2.5	5	49.9	47.4	1.3	1.6	467	7	595	574	572	543	571	478	1.19
3508680	Harikeerthana k	24	2	2	1	2	3	2	7.11	5.75	1.24	47.5	58.7	-2.2	176	49.7	47.6	1	1.1	464	5	596	557	561	557	567.75	470	1.21
3550941	Hemabindu kg	22	2	1	3	2	3	1	7.83	6.39	1.23	43.1	52.9	-0.6	7	44.8	44.3	0.5	1.1	476	7	606	552	561	547	566.5	484	1.17
3550941	Hemabindu kg	22	2	2	3	5	5	4	7.77	6.31	1.23	43.5	53.4	-0.3	167	44.8	44.5	1	1.2	476	6	609	551	566	530	564	486	1.16
3498712	Indhumathy p	24	2	2	3	2	1	4	7.69	6.21	1.24	43.9	54.3	-1	7	47.9	46.9	1.5	1.7	488	6	612	542	581	600	583.75	504	1.16
3498712	Indhumathy p	24	2	1	4	3	3	2	7.7	6.32	1.22	43.8	53.4	-0.6	177	46.4	45.8	0.9	2.3	497	7	610	603	566	553	583	508	1.15
3347217	Jagatheesh g	25	1	2	3	4	1	1	7.56	6.09	1.24	44.6	55.4	-1.7	117	49.4	47.7	1.7	2.2	482	7	560	556	569	540	556.25	488	1.14
3347217	Jagatheesh g	25	1	1	4	4	1	1	7.53	6.03	1.25	44.8	56	-1.8	69	49	47.2	1.5	2.4	487	8	564	566	561	551	560.5	478	1.17
3578309	Jayaprakashnarayanan r	24	1	2	2	5	4	1	7.38	5.85	1.26	45.7	57.7	-1.3	13	48.7	47.4	1.2	1.8	555	6	648	637	627	668	645	561	1.15
3578309	Jayaprakashnarayanan r	24	1	1	3	3	4	1	7.38	5.9	1.25	45.8	57.2	-1.9	174	49.2	47.3	1	2.4	568	7	633	646	636	642	639.25	574	1.11
3336870	Jenifer p	22	2	2	2	2	3	1	7.48	6.02	1.24	45.1	56.1	-2.4	172	48.4	46.1	1.3	2.1	590	6	701	657	655	673	671.5	598	1.12
3336870	Jenifer p	22	2	1	2	2	3	3	7.54	6.12	1.23	44.8	55.1	-2.4	1	48.2	45.8	1.1	1.7	608	7	706	677	665	666	678.5	618	1.10
3131521	Jenifer r	24	2	2	3	2	3	4	7.5	6.06	1.24	45	55.7	-2.3	175	48.8	46.6	0.8	1.9	597	6	697	645	655	680	669.25	609	1.10
3131521	Jenifer r	24	2	1	2	2	3	3	7.54	6.11	1.23	44.8	55.2	-2.2	1	47.9	45.7	0.6	1.4	601	7	706	677	642	663	672	612	1.10
3484665	Jeevithamani r	23	1	2	2	2	3	1	7.88	6.5	1.21	42.9	52	-1	12	44.7	43.7	0.8	1	469	5	559	535	543	543	545	474	1.15
3484665	Jeevithamani r	23	1	1	2	2	3	1	7.88	6.47	1.22	42.8	52.2	-1.8	15	44.7	42.9	0.7	0.8	462	8	541	555	560	542	549.5	475	1.16
3531625	Kamala s	26	2	1	3	2	3	2	7.54	6.27	1.20	44.8	53.8	-2.3	7	47.8	45.5	0.7	1.2	518	8	628	616	606	582	608	526	1.16
3531635	Kamala s	26	2	2	3	3	5	1	7.55	6.22	1.21	44.7	54.3	-1	174	46.6	45.6	1.3	2.6	519	1	584	569	615	607	593.75	523	1.14
3324348	Karthik ks	24	1	2	2	2	1	2	8.01	6.61	1.21	42.1	51	-1.4	9	47.1	45.7	2.1	2.3	528	7	636	604	588	589	604.25	535	1.13
3324348	Karthik ks	24	1	1	2	3	1	2	7.96	6.5	1.22	42.4	51.9	-1.7	173	47.3	45.6	2.8	3.1	526	6	629	593	582	611	603.75	534	1.13
3089870	Karthika k	21	2	1	2	2	3	1	8.1	6.65	1.22	41.7	50.8	-2.5	15	47.3	44.8	1.4	1.9	514	3	622	591	601	557	592.75	517	1.15
3089870	Karthika k	21	2	2	2	2	3	1	8.06	6.59	1.22	41.8	51.2	-2.1	164	44.6	42.5	1.4	1.7	511	6	623	589	599	574	596.25	516	1.16
3497662	Kathija m	21	2	2	2	3	4	2	7.25	6.02	1.20	46.6	56.1	-0.5	40	48.4	47.8	0.7	1.6	531	8	624	580	614	630	612	534	1.15
3497662	Kathija m	21	2	1	2	3	4	1	7.2	5.94	1.21	46.9	56.8	-0.9	161	48.6	47.7	1.1	1.2	531	8	629	619	612	603	615.75	538	1.14

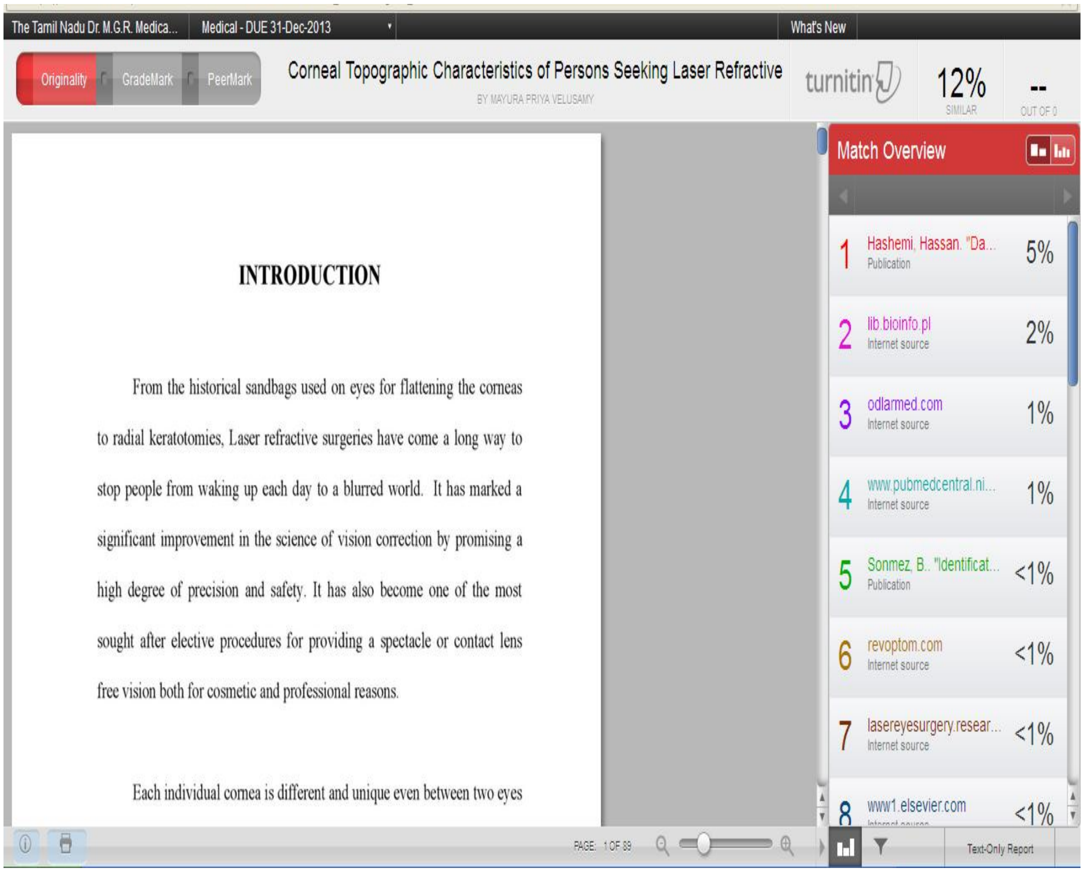
3494359	Kishore g	19	1	1	2	3	4	3	7.57	6.12	1.24	44.6	55.1	-6	15	53.6	47.6	5	5.2	409	7	578	577	542	541	559.5	424	1.32
3494359	Kishore g	19	1	2	1	2	4	3	7.33	5.89	1.24	46.1	57.3	-10.4	168	61.3	50.9	6.2	7.3	386	6	578	545	526	567	554	401	1.38
2842574	Kowsalya m	28	2	2	2	2	3	3	7.68	6.43	1.19	43.9	52.5	3.2	175	47.4	44.3	0.8	1.4	459	6	564	509	544	571	547	472	1.16
2842574	Kowsalya m	28	2	1	2	3	1	2	7.72	6.5	1.19	43.7	51.9	-1.9	9	46.5	44.6	1.1	1.8	459	7	571	589	539	501	550	478	1.15
3478306	Latha r	24	2	1	3	2	4	1	7.51	6.09	1.23	45	55.4	-0.3	139	47.1	46.9	1.4	2.2	467	6	596	551	552	581	570	478	1.19
3478306	Latha r	24	2	2	3	3	5	2	7.52	6.13	1.23	44.9	55.1	-0.9	46	47.8	46.9	1.8	2.7	471	7	613	595	552	561	580.25	481	1.21
2942972	Lilly lidiya jenifher j	22	2	2	2	5	5	1	7.27	6.01	1.21	46.4	56.2	-1.6	179	48.2	46.7	1.7	2.1	552	8	628	619	636	626	627.25	561	1.12
2942972	Lilly lidiya jenifher j	22	2	1	2	3	5	1	7.48	6.1	1.23	45.1	55.3	-0.9	11	46.5	45.6	1.3	1.5	557	5	641	638	648	625	638	562	1.14
3498639	Maddukiranmyee p	25	1	2	3	2	2	2	7.86	6.55	1.20	42.9	51.5	-1.3	161	47.5	46.2	1.2	1.8	493	5	592	567	584	556	574.75	498	1.15
3498639	Maddukiranmyee p	25	1	1	3	4	2	2	7.88	6.47	1.22	42.9	52.1	-0.9	27	45.4	44.6	1.3	1.9	475	6	601	563	590	597	587.75	486	1.21
3136870	Manickavasagam p	24	1	1	4	2	4	2	7.51	6.23	1.21	44.9	54.2	0.8	4	47.7	46.8	2.7	3.4	494	6	575	568	527	546	554	500	1.11
3136870	Manickavasagam p	24	1	2	4	5	4	2	7.51	6.19	1.21	44.9	54.5	-0.7	8	47.7	47.1	1.8	2.5	495	7	571	562	556	554	560.75	498	1.13
3528414	Manikandan k	21	1	1	3	5	1	1	8.11	6.68	1.21	41.6	50.5	-0.5	22	43	42.6	1.1	1.3	463	9	585	556	579	544	566	469	1.21
3528414	Manikandan k	21	1	2	2	2	1	1	8.14	6.78	1.20	41.5	49.7	-0.8	170	42.9	42.1	0.8	1.1	474	8	580	554	560	545	559.75	480	1.17
3475417	Manikandan k	28	1	1	2	2	1	2	7.89	6.43	1.23	42.7	52.5	-0.7	37	43.9	43.3	1.3	1.5	469	4	590	581	599	569	584.75	490	1.19
3475417	Manikandan k	28	1	2	2	3	2	2	7.85	6.37	1.23	43	53	-0.7	147	44.5	43.8	0.9	1.5	468	1	587	552	605	597	585.25	482	1.21
3074555	Manjunatha cv	27	1	1	3	3	4	2	7.64	6.21	1.23	44.2	54.3	-3.1	9	49.2	46.2	1.9	3.3	420	8	551	565	523	511	537.5	438	1.23
3074555	Manjunatha cv	27	1	2	3	3	4	3	7.7	6.13	1.26	44.4	55	-3.3	159	50	46.6	1.9	3.8	405	6	536	491	521	565	528.25	424	1.25
3232414	Mariselvi v	24	2	1	4	2	5	2	7.53	6.18	1.22	44.8	54.6	-0.4	176	46.9	46.6	0.9	1.8	499	7	614	578	573	579	586	505	1.16
3232414	Mariselvi v	24	2	2	4	2	1	4	7.49	6.11	1.23	45	55.2	-0.2	63	47.6	47.4	0.8	2	503	6	592	578	578	606	588.5	516	1.14
3483663	Mathanlal tr	24	1	2	3	2	3	2	7.48	5.98	1.25	45.1	56.4	-1.3	17	47.6	46.2	0.8	1.2	493	6	634	564	592	630	605	505	1.20
3483663	Mathanlal tr	24	1	1	3	2	3	1	7.47	5.98	1.25	45.2	56.4	-1.9	166	48.2	46.3	0.9	1.6	492	6	630	585	599	562	594	496	1.20
3259338	Mathar habeeb v	21	1	2	4	2	5	2	7.77	6.44	1.21	43.4	52.4	-0.7	174	45.6	44.9	1.1	2.1	497	7	597	534	580	595	576.5	502	1.15
3259338	Mathar habeeb v	21	1	1	3	2	4	2	7.81	6.4	1.22	43.2	52.7	-1.1	175	47.3	46.2	2.4	2.4	496	5	588	564	581	565	574.5	499	1.15
3377869	Meenakshi pr	23	2	1	2	2	1	1	8.21	6.62	1.24	41.1	50.9	-1.4	176	43.5	42.1	1.5	1.7	450	8	548	552	546	636	570.5	455	1.25
3377869	Meenakshi pr	23	2	2	3	3	1	1	8.31	6.7	1.24	40.6	50.4	-1.3	180	43.5	42.2	1.9	2.2	451	2	561	513	550	594	554.5	457	1.21
3497424	Meenakshisundaram c	34	1	2	5	5	5	3	7.74	6.5	1.19	43.6	51.9	-2.4	110	45.6	43.2	1.3	1.8	444	6	545	508	493	534	520	452	1.15
3497424	Meenakshisundaram c	34	1	1	2	3	5	4	7.76	6.59	1.18	43.5	51.2	-1.6	84	45.8	44.2	1.2	1.6	457	7	544	533	517	520	528.5	461	1.15
3020007	Mohamed sulthan a	22	1	1	3	2	5	2	7.84	6.42	1.22	43.1	52.5	-0.5	81	47.3	46.7	1.8	2.6	484	6	582	584	568	548	570.5	490	1.16
3020007	Mohamed sulthan a	22	1	2	3	5	5	2	7.86	6.41	1.23	42.9	52.7	-0.5	68	47.9	47.4	1.7	2.7	485	7	565	544	570	578	564.25	488	1.16
3421131	Mohanraj r	28	1	1	2	2	4	4	7.67	61.12	0.13	44	55.2	-0.7	77	44.9	44.2	4.6	5.1	435	7	598	582	483	523	546.5	471	1.16
3421131	Mohanraj r	28	1	2	2	5	1	2	7.71	6.29	1.23	43.8	53.7	-0.8	7	45.5	44.7	1	1.3	468	5	580	546	536	584	561.5	489	1.15
3266777	Moorthi a	25	1	1	5	5	5	2	7.61	6.21	1.23	44.3	54.4	-0.9	155	46.2	45.3	1.1	2.3	458	7	543	578	530	509	540	466	1.16
3266777	Moorthi a	25	1	2	4	2	1	1	7.71	6.28	1.23	43.7	53.8	-0.7	7	46	45.2	1.2	2.7	450	6	520	515	544	526	526.25	456	1.15
3127861	Murughanandham a	27	1	2	3	3	4	4	7.43	6.1	1.22	45.4	55.3	-2.3	116	48.8	46.5	1.3	2.2	459	6	575	518	529	589	552.75	478	1.16
3127861	Murughanandham a	27	1	1	3	3	4	4	7.4	6.04	1.23	45.6	55.9	-2.3	75	49.1	46.8	1.5	2.7	444	7	567	563	531	523	546	461	1.18
2988645	Murugavel m	23	1	1	2	2	3	1	7.41	5.94	1.25	45.6	56.8	-1.5	171	48.1	46.6	1	1.3	575	6	667	648	668	658	660.25	581	1.14
2988645	Murugavel m	23	1	2	3	3	3	1	7.45	5.89	1.26	45.3	57.3	-1.4	176	47.9	46.5	1	1.6	578	6	676	669	659	676	670	584	1.15
3378453	Muthukumar v	28	1	2	2	2	4	1	7.52	6.16	1.22	44.9	54.8	-1.5	8	47.9	46.4	2.3	2.9	497	6	585	557	569	601	578	501	1.15
3378453	Muthukumar v	28	1	1	3	2	4	1	7.5	6.13	1.22	45	55.1	0.9	180	47.2	46.3	1.5	3.1	482	6	575	572	560	557	566	487	1.16
3056491	Nagabhushana a	24	2	1	2	2	3	2	7.94	6.36	1.25	42.5	53.1	-3.5	90	47.3	43.9	2.1	2.7	496	7	578	569	553	574	568.5	502	1.13
3056491	Nagabhushana a	24	2	2	2	2	3	4	8	6.38	1.25	42.2	52.9	-3.2	93	47.2	44	1.9	2	485	7	609	552	555	591	576.75	503	1.15
3507932	Naresh v	28	1	2	2	2	3	2	7.74	6.17	1.25	43.6	54.7	-2.3	172	47.5	45.2	1.6	1.7	501	5	584	558	609	592	585.75	506	1.16
3507932	Naresh v	28	1	1	2	2	3	2	7.67	6.11	1.26	44	55.2	-1.9	12	46.5	44.6	0.8	1.4	500	7	621	605	578	548	588	508	1.16
3175968	Narmatha b	25	2	1	2	2	4	2	7.62	6.46	1.18	44.3	52.2	-1.9	168	47.7	45.8	1.1	1.6	494	4	568	554	550	549	555.25	499	1.11

3175968	Narmatha b	25	2	2	2	2	3	1	7.57	6.4	1.18	44.6	52.7	-2	10	47.3	45.4	0.8	1.5	504	9	574	556	556	556	560.5	507	1.11
3518942	Naveenkumar l	23	1	1	2	1	3	2	7.48	6.11	1.22	45.1	55.2	-1.3	177	47.4	46.1	0.9	1.3	493	8	603	566	579	542	572.5	497	1.15
3518942	Naveenkumar l	23	1	2	3	2	4	2	7.45	6.08	1.23	45.3	55.5	-1.2	176	47.5	46.3	1.1	1.4	492	7	598	566	596	561	580.25	501	1.16
3515837	Nithyapriya d	24	2	1	3	3	3	2	7.23	5.89	1.23	46.7	57.3	-0.9	13	48.7	47.7	0.9	1.3	533	7	638	615	575	609	609.25	541	1.13
3515837	Nithyapriya d	24	2	2	2	2	4	3	7.23	5.9	1.23	46.7	57.2	-1	167	48.2	47.2	1.3	1.2	539	5	646	589	604	652	622.75	544	1.14
3422823	Nivetha ut	21	2	2	4	2	2	2	7.55	6.07	1.24	44.7	55.6	-0.1	122	46.7	46.7	0.8	1.4	525	6	614	560	623	597	598.5	521	1.15
3422823	Nivetha ut	21	2	1	3	5	4	2	7.49	6.01	1.25	45.1	56.1	-0.4	138	47.5	47.1	0.9	2.9	508	8	581	578	608	565	583	511	1.14
3409167	Palanivel a	20	1	2	2	2	3	1	7.83	6.39	1.23	43.1	52.8	-2.1	148	45.8	43.7	1.9	2	468	7	600	540	561	575	569	484	1.18
3409167	Palanivel a	20	1	1	2	5	5	1	7.78	6.31	1.23	43.4	53.5	-1.8	16	46.2	44.4	1.6	2.1	463	8	572	591	584	527	568.5	478	1.19
3527307	Pandithurai p	23	1	1	2	2	3	1	7.25	5.8	1.25	46.6	58.1	-3.8	279	53.8	50	3	3.4	445	8	589	565	573	567	573.5	456	1.26
3527307	Pandithurai p	23	1	2	3	3	4	4	7.42	5.98	1.24	45.5	56.4	-1.4	22	48.6	47.2	1.5	1.8	473	6	588	562	585	608	585.75	495	1.18
3319206	Pandiganesh b	22	1	2	3	2	4	2	7.34	5.91	1.24	46	57.1	-1.2	6	48.2	47	1	1.4	539	6	609	609	609	632	614.75	543	1.13
3319206	Pandiganesh b	22	1	1	3	2	4	4	7.3	5.85	1.25	46.2	57.7	-1.4	2	48.5	47.1	1.7	2.8	538	7	599	658	601	596	613.5	544	1.13
3302909	Pandimuthu m	24	1	1	2	2	3	1	7.43	5.98	1.24	45.4	56.5	-0.9	114	47.7	46.8	0.8	1.7	565	7	643	635	612	634	631	572	1.10
3302909	Pandimuthu m	24	1	2	2	2	3	1	7.4	6.01	1.23	45.6	56.1	-0.9	56	47.5	46.6	1.1	2.5	566	7	661	623	609	683	644	571	1.13
3315354	Parvathi p	25	2	2	2	3	4	4	7.53	6.03	1.25	44.8	55.9	-1	170	47	45.8	1.2	1.7	466	3	594	545	542	601	570.5	476	1.20
3315354	Parvathi p	25	2	1	3	3	4	4	7.59	6.1	1.24	44.5	55.4	-1.3	6	46.9	45.5	1.1	2.1	477	7	618	606	539	518	570.25	497	1.15
3499321	Pavankumarganesuni l	29	1	2	2	2	1	1	7.96	6.71	1.19	42.4	50.3	-1.8	170	44.3	42.5	1.2	1.4	467	7	568	536	552	574	557.5	496	1.12
3499321	Pavankumarganesuni l	29	1	1	2	2	1	3	8	6.69	1.20	42.2	50.4	-1.7	13	44.2	42.5	0.8	1.1	461	7	562	563	540	536	550.25	485	1.13
3005523	Ponmanimanju p	24	2	1	3	2	3	1	7.33	5.9	1.24	46.1	57.2	-1	2	47.9	46.9	0.9	1.5	527	7	634	646	637	599	629	537	1.17
3005523	Ponmanimanju p	24	2	2	2	5	4	2	7.31	5.94	1.23	46.1	56.8	-1.3	12	48.2	46.9	1	1.5	543	6	655	623	614	647	634.75	549	1.16
3493602	Poonkodi s	34	2	1	2	5	3	1	7.36	6.33	1.16	45.9	53.3	-1.8	119	47.5	45.7	1.4	1.7	517	7	573	573	546	553	561.25	524	1.07
3538455	Poorani c	21	2	1	2	2	3	1	7.26	5.91	1.23	46.5	57.1	-1.5	12	48.2	46.7	1.2	1.7	611	7	737	716	674	647	693.5	616	1.13
3538455	Poorani c	21	2	2	2	2	3	1	7.26	5.84	1.24	46.5	57.8	-1.3	14	48.2	46.9	0.7	0.9	608	8	682	684	701	680	686.75	613	1.12
3536604	Poornima a	23	2	1	2	2	3	1	7.36	5.97	1.23	45.9	56.5	-2.4	180	48.7	46.4	1	1.1	528	8	634	609	574	572	597.25	531	1.12
3536604	Poornima a	23	2	2	2	2	3	1	7.34	5.95	1.23	46	56.7	-2.5	172	48.7	46.2	0.6	1.1	520	6	637	566	579	617	599.75	534	1.12
2946734	Prabhavathy j	22	2	1	2	2	4	2	7.32	5.99	1.22	46.1	56.3	-1.4	164	48.7	47.3	1.1	1.6	546	7	645	608	610	594	614.25	551	1.11
2946734	Prabhavathy j	22	2	2	3	2	4	2	7.27	5.93	1.23	46.4	56.9	-1.8	9	49.1	47.3	1	1.3	548	6	672	591	609	629	625.25	554	1.13
3303426	Praveen t	28	1	1	5	5	1	1	7.84	6.32	1.24	43.1	53.4	-1.1	66	43.7	42.6	1.1	1.8	447	6	587	576	526	541	557.5	460	1.21
3303426	Praveen t	28	1	2	5	5	5	4	7.82	6.32	1.24	43.2	53.4	-1	114	44.1	43	1	1.5	460	6	582	543	542	570	559.25	467	1.20
3499747	Praveen kumar s	23	1	2	2	3	4	3	7.86	6.32	1.24	42.9	53.4	-3.8	153	48.1	44.2	3.6	4.1	494	6	636	558	596	619	602.25	520	1.16
3499747	Praveen kumar s	23	1	1	3	2	4	3	7.71	6.22	1.24	43.8	54.3	-5.1	24	52.3	47.1	4.7	5.2	456	7	632	563	563	591	587.25	471	1.25
3063635	Preeda felcy m	29	2	2	3	3	1	2	8.21	6.58	1.25	41.1	51.3	-0.4	2	42.6	42.2	1	1.2	457	6	586	535	575	601	574.25	469	1.22
3063635	Preeda felcy m	29	2	1	2	2	1	1	8.2	6.68	1.23	41.2	50.5	-0.6	35	42.9	42.3	1.5	1.7	458	7	617	591	539	561	577	482	1.20
3303691	Preethi tg	21	2	1	5	3	3	1	8.47	6.98	1.21	39.9	48.4	-1	115	41.7	40.7	1.9	2.6	488	7	601	593	560	571	581.25	495	1.17
3303691	Preethi tg	21	2	2	5	3	1	1	8.54	7	1.22	39.5	48.2	-0.5	43	40.9	40.4	1	1.2	476	6	589	558	568	600	578.75	484	1.20
3377116	Prithi k	27	2	1	2	2	4	1	7.29	5.85	1.25	46.3	57.7	-2	11	49.2	47.2	1.3	1.7	547	4	631	634	619	590	618.5	550	1.12
3377116	Prithi k	27	2	2	2	2	4	4	7.3	5.9	1.24	46.3	57.2	-1.9	175	48.8	46.8	1.6	1.8	538	5	642	584	618	635	619.75	552	1.12
3226330	Priya m	23	2	2	4	3	5	1	7.11	6.71	1.06	47.5	59.1	-0.1	37	49.9	49.8	0.9	2.5	582	5	656	655	649	667	656.75	587	1.12
3226330	Priya m	23	2	1	4	5	1	2	7.12	6.76	1.05	47.4	58.6	-0.1	68	49.7	49.6	0.6	1.9	590	7	669	681	642	651	660.75	595	1.11
3330523	Pushpalatha t	25	2	2	3	2	4	4	7.55	6.08	1.24	44.7	55.5	-1.1	1	48.7	47.7	2.5	4.3	455	6	576	505	526	526	533.25	469	1.14
3330523	Pushpalatha t	25	2	1	3	3	4	4	7.56	6.07	1.25	44.6	55.6	-1.1	179	47.6	46.5	1.1	1.8	455	8	566	552	536	494	537	464	1.16
3557634	Radha t	26	2	2	2	2	4	1	7.34	5.64	1.30	46	57.8	-1.8	175	47.9	46.1	1.8	2	543	7	664	629	635	653	645.25	554	1.16
3557634	Radha t	26	2	1	2	2	3	1	7.31	5.94	1.23	46.2	56.9	-1.5	13	48	46.5	0.9	1.6	562	7	690	669	604	644	651.75	568	1.15
3231609	Rajagopaharivijay r	22	1	2	3	4	1	1	7.56	6.3	1.20	44.6	53.6	-0.4	43	47.9	47.6	1.4	1.4	520	6	613	586	597	596	598	530	1.13

3231609	Rajagopaharivijay r	22	1	1	2	4	1	1	7.54	6.26	1.20	44.7	53.9	-0.6	139	47.7	47.2	0.6	1.2	623	7	624	602	599	584	602.25	520	1.16
3511937	Rajeshwari m	26	2	2	4	4	1	1	7.28	6.07	1.20	46.3	55.6	-0.7	18	48.4	47.6	0.7	1.3	523	7	605	587	580	583	588.75	525	1.12
3511937	Rajeshwari m	26	2	1	3	4	4	1	7.29	6.14	1.19	46.3	55	-0.8	175	47.8	47	1.2	1.1	518	8	600	589	580	596	591.25	524	1.13
3089485	Ramanand n	22	1	1	3	2	2	2	8.17	6.75	1.21	41.3	50	-1.5	12	43.7	42.2	1.7	2	464	7	591	576	538	542	561.75	477	1.18
3290423	Ramya krishna g	24	2	2	2	2	4	1	7.4	6.01	1.23	45.6	56.2	-1	178	47.7	46.7	1	1.4	511	6	611	580	568	592	587.75	516	1.14
3290423	Ramya krishna g	24	2	1	2	2	4	4	7.44	6	1.24	45.4	56.2	-2	178	47.9	45.9	0.9	1.3	501	7	607	587	575	566	583.75	508	1.15
3559243	Remesh c	24	1	2	3	3	2	2	7.43	6	1.24	45.4	56.2	-0.7	41	48.2	47.5	0.8	2	470	6	587	526	541	555	552.25	474	1.17
3559243	Remesh c	24	1	1	4	4	4	1	7.38	6	1.23	45.7	56.3	-0.2	151	48.4	48.2	0.9	2.4	462	7	577	560	539	530	551.5	467	1.18
3499322	Ranjithkumar k	25	1	1	3	5	1	1	7.27	5.85	1.24	46.4	57.7	-0.4	36	42.9	43.4	1	1.8	512	8	596	596	578	557	581.75	516	1.13
3499322	Ranjithkumar k	25	1	2	4	5	1	2	7.3	5.9	1.24	46.3	57.2	-0.3	150	44.3	44	0.9	1.5	507	5	566	554	591	602	578.25	512	1.13
3508562	Rashmi rk	28	2	1	3	5	1	2	7.94	6.46	1.23	42.5	52.2	-0.4	150	47.3	46.8	1.6	2.7	485	7	596	559	559	553	566.75	491	1.15
3508562	Rashmi rk	28	2	2	4	2	2	2	7.91	6.45	1.23	42.7	52.3	-0.2	15	47.5	47.3	1.1	2.8	492	6	587	538	579	572	569	497	1.14
3545754	Ravikiran bhogadi v	31	1	1	2	2	4	2	7.73	6.33	1.22	43.7	53.3	-2.2	8	47.1	44.9	0.9	1.9	457	8	566	534	552	529	545.25	464	1.18
3545754	Ravikiran bhogadi v	31	1	2	3	2	3	2	7.76	6.35	1.22	43.5	53.1	-2.3	174	47.3	45	0.8	1.5	459	5	580	504	552	576	553	469	1.18
3299780	Ravindran c	25	1	2	2	3	2	2	7.92	6.44	1.23	42.6	52.4	-1.9	160	44.7	42.7	1.3	1.6	417	6	560	481	541	571	538.25	430	1.25
3299780	Ravindran c	25	1	1	2	2	4	2	7.92	6.36	1.25	42.6	53	-2.9	35	45.2	42.3	1.6	1.8	408	7	563	545	538	488	533.5	417	1.28
3296124	Raghavendran j	20	1	2	2	2	4	2	7.53	6.15	1.22	44.8	54.8	-1.8	5	47.1	45.3	1	1.3	463	5	571	539	589	562	565.25	478	1.18
3296124	Raghavendran j	20	1	1	1	2	3	2	7.56	6.2	1.22	44.7	54.5	-1.9	9	47.1	45.1	0.6	1.3	468	7	614	576	580	544	578.5	497	1.16
3475669	Rejin r	19	1	1	2	2	2	2	7.71	6.13	1.26	43.8	55.1	-3.9	7	46.7	42.8	1.2	1.7	441	8	562	549	543	518	543	446	1.22
3475669	Rejin r	19	1	2	2	2	3	4	7.77	6.25	1.24	43.4	54	-3.7	166	46.3	42.6	1.7	1.9	443	6	574	482	534	594	546	452	1.21
3228114	Resmi s	23	2	2	2	3	5	2	7.77	6.27	1.24	43.4	53.9	-0.2	21	44.4	44.2	1.5	1.7	468	8	565	563	589	576	573.25	481	1.19
3228114	Resmi s	23	2	1	3	5	4	2	7.91	6.5	1.22	42.7	52.8	-1.2	15	44.8	43.6	1.2	1.6	462	5	559	559	559	543	555	475	1.17
3456112	Rubini d	21	2	2	3	3	2	3	7.45	6.14	1.21	45.3	55	-0.2	148	47.3	47.1	1.1	1.6	555	6	658	606	634	637	633.75	568	1.12
3456112	Rubini d	21	2	1	4	3	5	4	7.47	6.27	1.19	45.2	54.7	-0.3	34	46.7	46.4	0.9	1.3	553	7	651	618	617	612	624.5	562	1.11
3246566	Sabana jasmine s	24	2	2	4	3	3	1	7.53	6.23	1.21	44.8	54.2	-1.1	13	47.4	46.3	0.9	2.1	519	6	616	567	587	608	594.5	523	1.14
3246566	Sabana jasmine s	24	2	1	3	3	4	2	7.54	6.25	1.21	44.8	54	-1.5	176	47.4	45.9	0.8	1.5	524	7	625	606	588	580	599.75	529	1.13
3483703	Sakthivel n	30	1	1	2	2	3	4	7.45	6.1	1.22	45.3	55.3	-2.2	177	47.9	45.7	1.1	1.7	496	8	574	602	579	520	568.75	505	1.13
3483703	Sakthivel n	30	1	2	3	2	4	4	7.58	6.2	1.22	44.6	54.5	-1.3	11	46.9	45.5	1.4	1.7	492	6	597	534	576	595	575.5	501	1.15
3293991	Sangeetha s	22	2	1	3	4	4	2	7.82	6.51	1.20	43.2	51.9	-0.7	156	47.8	47.1	2	2.3	486	7	587	581	546	560	568.5	492	1.16
3293991	Sangeetha s	22	2	2	2	3	3	1	7.72	6.41	1.20	43.7	52.7	-0.8	17	47.3	45.5	1.9	2.1	488	6	585	571	570	596	580.5	492	1.18
3011608	Saijtha parveen s	26	2	2	2	2	3	1	7.77	6.34	1.23	43.4	53.2	-1.4	5	45.5	44.1	0.8	1.4	471	6	579	546	563	597	571.25	478	1.20
3515683	Saranya d	24	2	1	2	3	3	1	7.59	5.99	1.27	44.5	56.3	-1.1	14	47	45.9	0.8	1.2	531	7	642	629	629	629	632.25	537	1.18
3515683	Saranya d	24	2	2	3	2	3	4	7.52	5.94	1.27	44.9	56.8	-1.2	11	47.8	46.7	1	1.5	529	6	661	606	637	663	641.75	540	1.19
2900421	Saravanaraju mp	29	1	1	3	2	2	1	7.62	6.13	1.24	44.3	55	-1.3	3	46.7	45.3	1.1	1.3	498	8	609	588	580	578	588.75	503	1.17
2900421	Saravanaraju mp	29	1	2	2	2	4	3	7.57	6.17	1.23	44.6	54.7	-1.5	168	47.3	45.8	1.1	1.7	498	5	612	563	580	593	587	505	1.16
3552672	Saravanakumar ss	21	1	1	3	2	4	1	7.41	5.99	1.24	45.5	56.3	-1.9	1	48.8	47	1.8	2.2	570	8	653	657	652	628	647.5	576	1.12
3552672	Saravanakumar ss	21	1	2	3	3	3	1	7.21	5.77	1.25	46.7	58.4	-1.8	176	49.7	47.8	1	2.4	554	6	656	619	632	685	648	558	1.16
3320517	Saravanan g	32	1	2	3	3	3	2	7.45	6.9	1.08	45.3	55.5	-1.2	15	49.6	48.4	1.8	4.6	549	6	627	602	605	614	612	557	1.10
3320517	Saravanan g	32	1	1	4	2	4	4	7.54	6.16	1.22	44.7	54.8	-0.8	138	48.3	47.5	1.3	3	547	8	619	643	602	558	605.5	552	1.10
3355593	Saravanan m	29	1	2	2	2	3	3	7.26	5.91	1.23	46.5	57.2	-1.9	178	49.5	47.5	1.7	2	607	8	677	657	664	647	661.25	613	1.08
3355593	Saravanan m	29	1	1	3	5	4	4	7.06	5.72	1.23	47.8	59	-3.6	2	52.6	49	2.9	3.6	600	8	638	682	653	658	657.75	604	1.09
3064416	Saraya v	25	2	2	3	3	1	3	7.8	6.39	1.22	43.3	52.8	-0.4	13	45.8	45.4	1.1	2.2	496	6	602	555	592	597	586.5	512	1.15
3064416	Saraya v	25	2	1	5	2	2	2	7.73	6.39	1.21	43.7	52.9	-0.9	148	45.8	44.9	1.2	1.7	499	7	599	569	591	563	580.5	503	1.15
3302151	Sravani m	23	2	1	3	2	1	2	7.82	6.46	1.21	43.2	52.2	-1.3	171	46	44.7	0.8	1.6	454	8	566	558	536	520	545	459	1.19
3302151	Sravani m	23	2	2	3	2	4	2	7.7	6.31	1.22	43.8	53.5	-1.7	1	47	45.3	0.8	1.7	453	6	583	529	536	573	555.25	467	1.19

3500495	Sathyabama d	23	2	1	2	2	3	1	7.44	6.08	1.22	45.4	55.5	-2.8	2	48.2	45.4	0.9	1.3	521	7	606	603	594	572	593.75	527	1.13
3500495	Sathyabama d	23	2	2	2	2	3	4	7.35	6.03	1.22	45.9	56	-2.8	172	48.3	45.5	0.6	1.2	517	6	632	573	579	616	600	530	1.13
3476719	Selvamani d	29	1	1	3	5	3	1	7.94	6.48	1.23	42.5	52.1	-2.2	1	47.4	45.2	1.2	1.6	492	7	594	577	571	556	574.5	498	1.15
3476719	Selvamani d	29	1	2	3	2	2	4	7.96	6.52	1.22	42.4	51.8	-1	165	44.2	43.3	1.2	2.2	490	6	610	551	571	604	584	503	1.16
3555571	Shaiksaalim s	22	1	2	1	1	3	2	7.55	6.25	1.21	44.7	54	-3.7	179	48.5	44.7	1	1.7	476	8	593	544	567	561	566.25	484	1.17
3555571	Shaiksaalim s	22	1	1	2	2	3	2	7.53	6.22	1.21	44.8	54.2	-2.8	174	47.9	45.1	1.6	1.8	460	7	600	574	545	542	565.25	470	1.20
3499220	Sham mohammed f	36	1	1	2	3	1	1	7.7	6.24	1.23	43.8	54	-0.1	46	46	45.9	1.1	2.6	459	7	593	548	558	539	559.5	465	1.20
3499220	Sham mohammed f	36	1	2	3	2	3	4	7.85	6.44	1.22	43	52.4	-0.6	151	44.8	44.2	1	1.9	460	6	600	526	561	563	562.5	470	1.20
3529068	Shanthi m	37	2	2	3	5	4	2	7.34	6	1.22	46	55.3	-0.9	51	48.7	47.8	0.7	1.5	541	6	637	588	578	620	605.75	548	1.11
3529068	Shanthi m	37	2	1	4	5	2	1	7.37	6.04	1.22	45.8	55.9	-0.6	118	48	47.4	1	1.5	553	1	640	612	583	594	607.25	556	1.09
3481192	Shanthi p	31	2	2	3	3	3	1	7.56	6.03	1.25	44.6	56	-1.7	69	49.4	47.7	1.7	2.2	482	7	560	596	569	542	566.75	488	1.16
3481192	Shanthi p	31	2	1	3	2	4	1	7.53	6.09	1.24	44.8	55.4	-1.8	117	49	47.2	1.7	2.2	487	8	568	566	556	551	560.25	491	1.14
3267534	Shenbaha valli b	27	2	2	3	3	1	4	7.69	6.36	1.21	43.9	53	-0.3	149	45.5	45.2	0.4	1.2	462	6	579	499	533	573	546	470	1.16
3267534	Shenbaha valli b	27	2	1	3	5	2	2	7.7	6.34	1.21	43.8	53.2	-0.5	113	45.5	45	1	1.4	467	4	582	544	520	520	541.5	466	1.16
3176496	Sharmila m	30	2	1	2	3	2	4	7.82	6.4	1.22	43.1	52.7	-0.4	171	44.4	44	0.9	1.4	451	7	579	556	510	540	546.25	463	1.18
3176496	Sharmila m	30	2	2	5	3	4	2	7.83	6.46	1.21	43.1	52.3	-0.7	175	44.7	44	1.1	1.6	458	6	572	538	516	547	543.25	464	1.17
3473680	Shruthi d	22	2	2	3	2	1	4	7.96	6.54	1.22	42.4	51.6	-0.2	142	44	43.8	0.7	1.4	469	6	585	515	558	542	550	472	1.17
3473680	Shruthi d	22	2	1	3	2	1	3	7.97	6.58	1.21	42.4	51.3	-0.3	87	43.2	43	0.6	1	468	7	583	523	540	422	517	475	1.09
3343364	Sivakumar v	20	1	2	2	2	2	4	7.76	6.4	1.21	43.5	52.8	-0.7	3	45.3	44.6	1.7	2.1	460	7	553	497	540	553	535.75	471	1.14
3343364	Sivakumar v	20	1	1	2	2	5	1	7.56	6.22	1.22	44.7	54.3	-1.2	29	45.7	44.5	0.9	1.1	457	6	554	525	554	531	541	461	1.17
3156617	Sivaraman v	29	1	1	1	2	2	2	8.2	6.96	1.18	41.1	48.5	-1.8	170	43.4	41.5	2.3	2.1	464	7	561	537	538	524	540	470	1.15
3531487	Sivaranjani b	25	2	1	3	2	4	1	7.6	6.27	1.21	44.4	53.9	-0.9	172	47.3	46.4	1.3	2.3	555	7	641	625	611	585	615.5	559	1.10
3531487	Sivaranjani b	25	2	2	3	2	4	1	7.51	6.2	1.21	44.9	54.4	-1.1	22	47.4	46.4	1	1.6	556	5	639	602	598	627	616.5	560	1.10
3482488	Sivaranjani v	31	2	1	2	2	1	1	7.68	6.31	1.22	44	53.5	-1.2	168	47.3	45.1	0.9	1.2	505	6	590	566	598	588	585.5	509	1.15
3482488	Sivarnajani v	31	2	2	3	3	1	1	7.64	6.28	1.22	44.2	53.7	-0.8	2	46.2	45.4	0.8	1.3	498	7	596	573	585	583	584.25	507	1.15
3510979	Srievidhyajanani e	28	2	2	2	4	4	2	7.94	6.58	1.21	42.5	51.3	-1.1	85	44.9	43.8	1.4	1.5	469	5	568	536	560	540	551	477	1.16
3353895	Subashini s	21	2	2	3	2	1	1	7.35	6.03	1.22	45.9	56	-2.8	172	47.3	44.5	0.7	1.2	520	6	634	573	578	614	599.75	532	1.13
3353895	Subashini s	21	2	1	3	2	1	1	7.3	6	1.22	46.3	55.3	-0.9	51	48.7	47.8	0.7	1.6	540	6	636	588	574	599	599.25	550	1.09
3502672	Subha v	25	2	2	2	2	3	2	7.16	5.89	1.22	47.1	57.3	-1.1	179	48.3	47.3	0.8	1	584	6	698	556	653	678	646.25	595	1.09
3502672	Subha v	25	2	1	2	2	3	1	7.16	5.92	1.21	47.2	57	-1.3	177	48.5	47.2	1.1	1.2	584	7	706	683	643	634	666.5	595	1.12
3478497	Sujitha g	24	2	1	4	3	2	4	7.6	6.26	1.21	44.4	53.9	-0.8	180	47.4	46.6	1.1	1.8	419	7	534	509	517	472	508	432	1.18
3478497	Sujitha g	24	2	2	4	3	2	4	7.6	6.22	1.22	44.4	54.3	-0.4	174	47.3	46.9	0.9	1.9	434	2	540	480	524	514	514.5	440	1.17
3305580	Swetha s	27	2	2	2	3	2	1	7.67	6.21	1.24	44	54.3	-1.8	165	46.7	44.9	1.5	2.4	461	6	589	570	553	573	571.25	471	1.21
3305580	Swetha s	27	2	1	3	3	2	1	7.71	6.25	1.23	43.8	54	-0.9	159	46.2	45.4	0.9	1.6	466	1	591	585	553	554	570.75	482	1.18
3244768	Tamilselvamari m	24	2	2	2	2	3	4	7.62	6.23	1.22	44.3	54.2	-1.7	166	47.3	45.6	1.2	1.6	553	5	626	592	650	641	627.25	561	1.12
3244768	Tamilselvamari m	24	2	1	2	2	3	3	7.56	6.11	1.24	44.6	55.3	-2.1	16	47.9	45.7	1.1	1.6	561	8	625	667	668	610	642.5	573	1.12
3066143	Tamilchezhian	20	1	1	2	4	1	3	7.45	6.3	1.18	45.3	53.6	-0.3	12	47.3	46.9	1.1	2	432	6	563	554	516	531	541	450	1.20
3066143	Tamilchezhian	20	1	2	2	4	2	4	7.5	6.28	1.19	45	53.7	-0.9	161	47.3	46.4	1	1.8	431	6	563	512	522	553	537.5	442	1.22
3490114	Thasarathan c	25	1	1	3	2	4	4	7.46	6.09	1.22	45.2	55.5	-0.9	103	47.6	46.8	1.5	2	474	4	568	580	547	552	561.75	488	1.15
3490114	Thasarathan c	25	1	2	3	2	4	2	7.4	6.12	1.21	45.6	55.2	-1.2	44	48.3	47	1.6	2.3	473	6	576	553	557	591	569.25	480	1.19
3526107	Thatchana moorthi m	26	1	2	3	3	1	3	8.05	6.56	1.23	41.9	51.4	-0.4	64	43.6	43.2	1	1.5	463	6	580	531	558	630	574.75	493	1.17
3526107	Thatchana moorthi m	26	1	1	5	2	1	1	8.08	6.63	1.22	41.8	50.9	-0.2	93	44.4	44.2	0.8	2.6	481	8	577	589	542	548	564	485	1.16
2730604	Velan m	26	1	1	3	2	2	2	7.64	6.29	1.21	44.2	53.7	-1	155	47.8	46.9	1.3	2.6	564	7	643	668	616	593	630	577	1.09
2730604	Velan m	26	1	2	3	2	4	1	7.53	6.19	1.22	44.8	54.5	-1.7	14	47.4	45.7	1.3	1.7	571	2	652	599	623	685	639.75	579	1.10
3512581	Venkatesh g	23	1	1	2	2	1	3	7.67	6.3	1.22	44	53.6	-0.8	161	46.9	46	1.2	1.4	466	7	602	591	551	535	569.75	496	1.15

3512581	Venkatesh g	23	1	2	2	2	2	2	7.63	6.18	1.23	44.2	54.6	-1.2	10	47.1	45.9	1.2	1.4	462	5	593	528	559	602	570.5	489	1.17
3519622	Venkaresh prasad m	34	1	1	2	3	4	1	7.54	6.19	1.22	44.8	54.5	-2.4	1	48.2	45.8	1.1	1.7	608	7	704	678	664	668	678.5	612	1.11
3519622	Venkaresh prasad m	34	1	2	2	3	3	2	7.53	6.06	1.24	44.8	55.7	-2.3	175	48.8	46.6	0.9	2.2	590	6	687	639	644	657	656.75	589	1.12
3093980	Vidyavathi pn	21	2	1	3	5	1	2	7.6	6.06	1.25	44.4	55.7	-1.9	179	47.6	45.7	0.9	1.5	519	6	621	586	601	610	604.5	525	1.15
3093980	Vidyavathi pn	21	2	2	2	2	4	2	7.5	6.26	1.20	45	53.9	-1.6	180	48.1	46.5	0.9	1.3	546	6	660	587	604	639	622.5	539	1.15
3507326	Vignesh n	24	1	2	3	2	4	2	7.91	6.51	1.22	42.6	51.8	-1.6	4	45.4	43.8	1.2	1.6	458	6	599	534	547	536	554	465	1.19
3507326	Vignesh n	24	1	1	2	2	4	2	7.89	6.45	1.22	42.8	52.4	-1.7	173	45.4	43.7	1.5	1.5	452	4	595	541	559	519	553.5	464	1.19
3265880	Vidhya lakshmi r	28	2	2	3	2	2	4	7.67	6.26	1.23	44	53.9	-1.2	26	47.3	46.1	1.7	3.6	485	6	573	545	569	558	561.25	500	1.12
3265880	Vidhya lakshmi r	28	2	1	2	2	2	2	7.62	6.21	1.23	44.3	54.3	-1.6	178	46.6	45	1.7	2.6	478	6	612	574	577	534	574.25	499	1.15
3485495	Vijayakumar ps	21	1	1	3	3	2	2	7.75	6.32	1.23	43.5	53.4	-1.2	16	47.4	46.3	1	1.7	489	7	596	606	582	533	579.25	501	1.16
3485495	Vijayakumar ps	21	1	2	3	3	1	3	7.82	6.39	1.22	43.2	52.8	-1.3	158	46	44.7	0.9	1.9	506	2	610	555	589	614	592	517	1.15
3264766	Vijayalakshmi r	32	2	1	3	3	4	1	7.27	6.01	1.21	46.4	56.2	-0.3	92	47.5	47.3	1	1.1	582	7	687	683	646	645	665.25	591	1.13
3264766	Vijayalakshmi r	32	2	2	2	3	4	1	7.26	5.9	1.23	46.5	57.2	-0.9	75	48.1	47.2	0.6	1	562	2	664	644	639	668	653.75	567	1.15
3473948	Vijayalakshmi n	23	2	2	4	2	4	2	7.59	6.24	1.22	44.5	54.3	-0.8	168	46.9	46	0.9	1.5	454	6	585	535	555	534	552.25	461	1.20
3473948	Vijayalakshmi n	23	2	1	4	3	2	4	7.65	6.32	1.21	44.1	53.4	-0.5	13	46.3	45.8	0.8	1.4	453	7	562	547	539	512	540	462	1.17
3253093	Vijayalakshmi v	22	2	2	2	2	3	4	7.37	5.92	1.24	45.8	57.1	-3.8	1	48.7	44.9	1.4	1.7	501	2	600	574	592	617	595.75	508	1.17
3253093	Vijayalakshmi v	22	2	1	2	2	4	1	7.35	6	1.23	45.9	56.3	-3.4	175	49.4	45.9	0.9	1.7	510	7	626	642	603	567	609.5	523	1.17
2401561	Vinoth m	20	1	1	2	2	4	1	7.57	6.07	1.25	44.6	55.6	-1.9	25	47.1	45.2	1.8	2.3	531	4	650	662	665	632	652.25	540	1.21
2401561	Vinoth m	20	1	2	3	3	1	3	7.58	6.04	1.25	44.5	55.9	-0.8	141	47	46.2	1.3	2	533	5	647	605	665	659	644	548	1.18
3187696	Vishnupriya tl	28	2	1	2	2	3	4	7.5	6.08	1.23	45	55.5	-2.5	178	47.8	45.3	0.8	1.3	483	7	622	574	562	525	570.75	491	1.16
3187696	Vishnupriya tl	28	2	2	2	2	3	4	7.53	6.1	1.23	44.8	55.4	-2.7	174	48.1	48.3	1.2	1.6	464	5	601	518	573	584	569	475	1.20
3535664	Vishnuvarathan s	29	1	1	2	3	1	1	8.21	6.66	1.23	41.1	50.7	-0.8	17	43.2	42.4	1	1.5	463	7	567	563	560	552	560.5	483	1.16
3535664	Vishnuvarathan s	29	1	2	3	3	1	3	8.21	6.65	1.23	41.1	50.7	-0.5	170	43	42.5	1.3	1.7	466	6	578	535	557	571	560.25	480	1.17
3478753	Vivekram v	25	1	1	2	2	3	2	7.44	6.11	1.22	45.4	55.3	-0.6	32	47.5	47	1.3	1.6	521	5	607	589	609	610	603.75	542	1.11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INTRODUCTION
From the historical sandbags used on eyes for flattening the corneas to radial keratotomies, Laser refractive surgeries have come a long way to stop people from waking up each day to a blurred world. It has marked a significant improvement in the science of vision correction by promising a high degree of precision and safety. It has also become one of the most sought after elective procedures for providing a spectacle or contact lens free vision both for cosmetic and professional reasons.
Each individual cornea is different and unique even between two eyes
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INTRODUCTION From the historical sandbags used on eyes for flattening the corneas to radial keratotomies, Laser refractive surgeries have come a long way to stop people from waking up each day to a blurred world. It has marked a significant improvement in the science of vision correction by promising a high degree of precision and safety. It has also become one of the most sought after elective procedures for providing a spectacle or contact lens free vision both for cosmetic and professional reasons. Each individual cornea is different and unique even between two eyes of the same individual. The more information we get about the surface of the cornea, much easier is it to understand its...